An Investigation of Interaction Design of Virtual Simulation Experiment

ABSTRACT

This paper aimed to study What are the interaction design strategies for VSE? The samples were Scoring of user experience parameters for VSE by students. The instrument for collecting data was Questionnaire Star WeChat Mini Program. Analysis data by descriptive statistics and content analysis. The research results were found as follows;

1. The design strategies of perceptual interaction include (1) Style should be adapted. (2) Design should be simple. (3) Navigation should be convenient. (4) Colors should be harmonious. (5) Elements should be unified. (6) Information should be readable. (7) Scene should be simulated. (8) Design should be interesting.

2. The design strategies of behavioral interaction include (1) Ensure the realism of the experiment. (2) Set explicit guidance information. (3) Provide clear targeted feedback. (4) Maintain system availability. (5) Keep the system operational. (6) Keep the system visibility. (7) Keep the system flexibility. (8) Keep the system open.

3. The design strategies of emotional interaction include (1) Find out the characteristics of user groups. (2) Ensure that users quickly grasp the use of methods. (3) Reduce the difficulty of the experiment. (4) Ensure the fluency of the experiment. (5) Create emotional resonance. (6) Provide emotional support.

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Keywords : Virtual Simulation Experiment; Perceptual Interaction; Behavioral Interaction; Emotional Interaction; User Experience

Article history :
Received : 01/10/67
Revised : 20/11/67
Accepted : 06/12/67

Introduction

In order to solve the problems of high risk, high investment, unable to copy the scene and irreversible experimental results in experimental teaching, the Ministry of Education of the People's Republic of China has introduced a new form of experimental teaching, VSE (Virtual Simulation Experiment), which has become an important application of virtual reality technology in the field of education. VSE is an efficient, safe and economical experiment (Wang, W. 2013), which integrates multimedia, human-computer interaction, database and network communication technologies, integrates psychological theory and design theory, and enables students to carry out efficient, safe and economical experiments in an open, autonomous and interactive virtual environment by constructing realistic experimental operating environment and experimental objects. In order to ensure the comprehensive and rapid development of VSE, the Ministry of Education of the People's Republic of China (2017) has launched a series of policies and measures: released the construction plan or the construction of about 1000 demonstration VSE teaching projects in 2017-2020; It is proposed that the "National Virtual Simulation Experimental Teaching Project" should be included in the important content of the special project of education and teaching reform in central universities during the 13th Five-Year Plan period (Ministry of Education of the People's Republic of China, 2019), and the plan of building about 1500 first-class courses of national virtual simulation experimental teaching is put forward (Ministry of Education of the People's Republic of China, 2019). With the introduction of a series of incentive policies and construction guidance, a large number of VSE courses are constantly emerging, only the National VSE Teaching Course Sharing Platform (https://www.ilab-x.com) covers 4795 VSE courses, covering 40719 knowledge points, and the number of experimenters is as high as 15 million +, which opens up a new plate for experimental teaching in Colleges and universities.

While the number of VSE is expanding, the overall construction quality is not satisfactory, mainly reflected in the user experience level. According to the use of more than 100 virtual simulation experimental courses of art and design disciplines in the National VSE Teaching Course Sharing Platform, the following problems are common: the text is not beautiful enough, the information readability is not high; the graphic expression is not clear, the form is not uniform; the simulation of model and scene design is not high, which affects the generation of experimental immersion; If the steering control has no boundary setting or rotates too fast, it is easy to cause vertigo; the guidance information is not clear, and there is a lack of control freedom; The loading time is too long, the running is not smooth enough, etc. Therefore, the relevant departments have put forward the construction goal of "VSE Teaching 2. 0" (Ministry of Industry and Information Technology of the People's Republic of China, 2022), which requires that the construction and development of VSE should be student-

centered, emphasize user experience, and effectively enhance students' interest in learning and learning effect. This has become the main research content of this research paper.

Research Objectives

This research paper aims at the problems existing in the user experience of VSE, guided by the idea of interaction design, relying on the relevant theories of psychology and design, combining with the development practice of specific cases, studies and explores the interaction design strategies of VSE, effectively improves the user experience and teaching effectiveness, and expands its research horizon in the design level. It provides theoretical guidance and practical reference for other development teams and scientific research institutions. The research practice framework is shown in Fig.1. The specific research objectives include: (1) Exploring the interaction design strategies of VSE at the perceptual level; (2) Exploring the interaction design strategies of VSE at the behavioral level; and (3) Exploring the interaction design strategies of VSE at the emotional level.

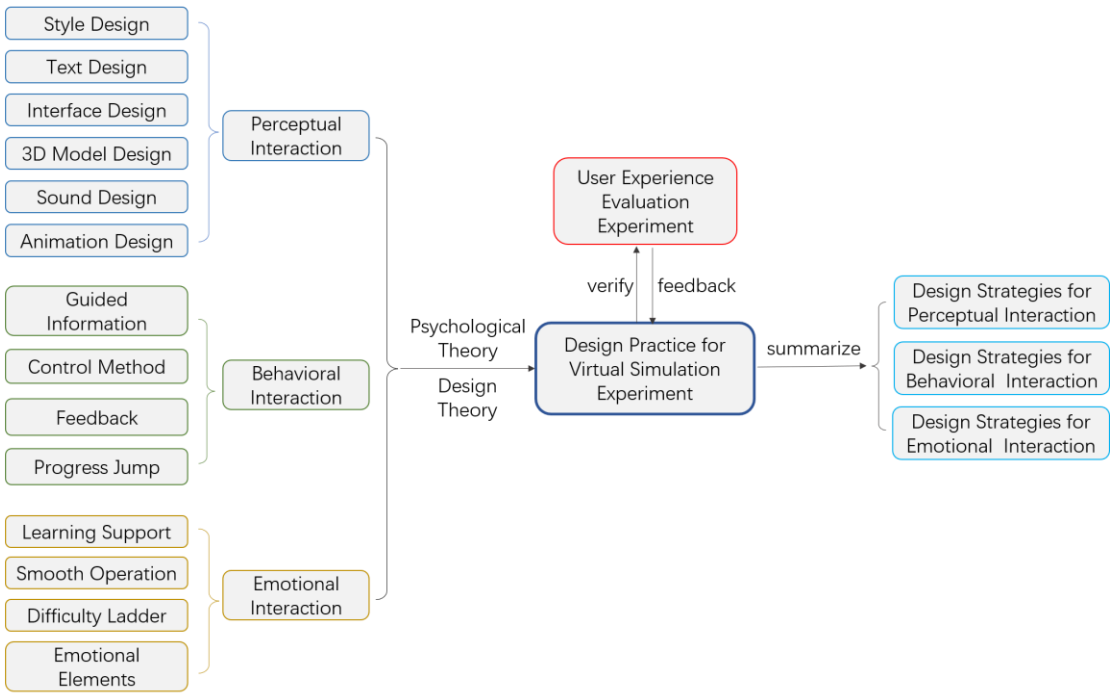

Fig. 1 Practical research framework

Literature Review

The related academic research of VSE has also developed rapidly with the policy guidance of government departments. Fig.2 shows the annual publication curve of VSE research literature in CNKI. By 2021, the number of relevant literature has reached 675. There

are 225 relevant books available in the academic database of Reading Show (as shown in Fig.3), of which 168 are published after 2015. VSE research has been paid more and more attention by the majority of scholars, and has become one of the research hotpots of experimental teaching in colleges and universities.

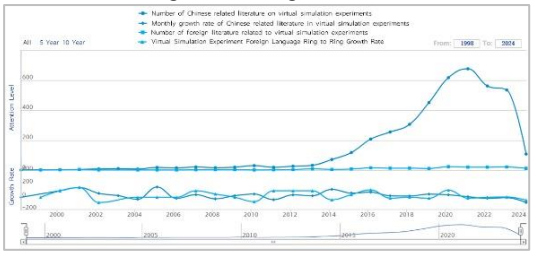

Fig.2 Academic attention chart of VSE

Fig.3 Annual distribution of the number of VSE books published

Whether it is journal papers or theoretical works, the main disciplines of its research are mainly distributed in science and engineering and education disciplines (as shown in Fig. 4 and Fig.5), mainly introducing the experimental design, use introduction and parameter setting of specific VSE courses, and the related research on VSE from the perspective of art design is still in a blank state.

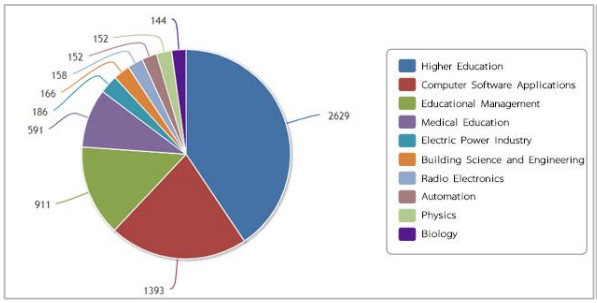

Fig.4 Discipline distribution of VSE in CNKI

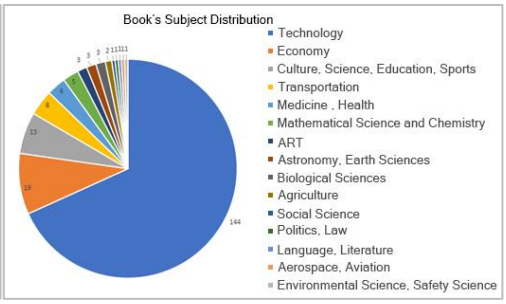

Fig.5 Discipline distribution of VSE in Reading Show

In this paper, VSE is regarded as a special type of product design, which is student-centered and emphasizes user experience. From the perspective of psychology and design, a theoretical framework suitable for its research is derived (as shown in Fig.6).

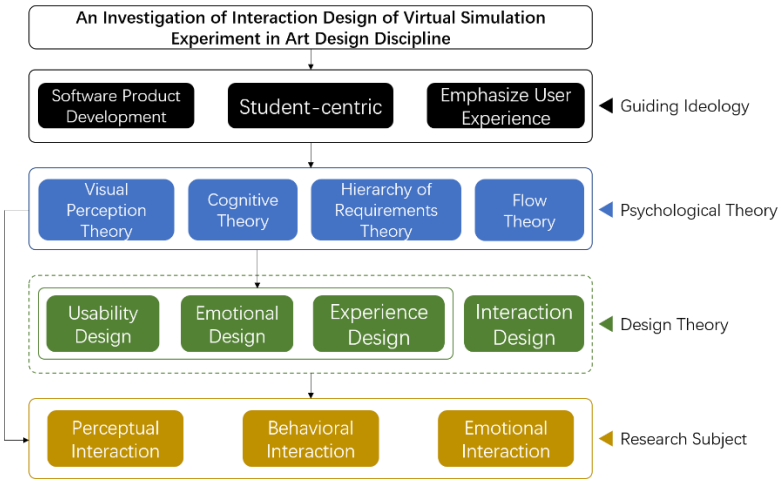

Fig.6 Theoretical research framework of VSE

1. Psychological theory has been widely used in the field of product design.

Design comes from life and serves consumers, both rational and emotional. Understanding the physiological characteristics, behavior habits and psychological models of users is an indispensable step in design. The starting point of the theory of visual perception is that "All perception contains thinking, all reasoning contains intuition, and all observation contains creation" (Rudolf, A. 1988), emphasizing that the process of visual perception itself is a process of thinking and creation (Li, J. & Liu, Y., 2021). There are abundant literatures on the application of visual perception theory to design research. The representative applications are as follows: analyzing the influence of color on emotion and cognition, and constructing the color cognition model (Gao, Y. et al., 2016) ; The eye tracker was used to generate the experimental data of the first fixation schedule of the interface, the average correct rate of product operation and the reaction schedule, which provided a new direction for the establishment of the scientific theory and method of human-computer interaction (Xie, W. et al., 2015) . According to the visual physiological characteristics of the elderly, this paper summarizes the detailed standards and specifications for the aging design of information products in font design, color recognition, layout design (Yang, Z., 2012), etc. The hierarchy of needs theory holds that people need motivation to fulfill certain needs, and that some needs take precedence over others (Maslow, A. H., 1943). According to the theory of hierarchy of needs, the related research on improving product use experience includes: by discussing the three different levels of needs of users in interaction design, the design strategy that should be adopted to meet the needs of users in interaction design is put forward (Ye, D. & Li, S., 2013) ; By analyzing the spiritual needs of the elderly, the design strategy of information products for the elderly is summarized (Wei, J. & Li, F., 2017) ; A method for predicting the

future development trend by establishing the mapping relationship between user requirements and product characteristics (Pu, J. et al., 2011) , etc. Cognitive theory holds that the learning process is the formation of cognitive map, in which the concepts of "Mental model", "Interface metaphor" and "Functional visibility" are very important for the establishment of interaction design theory. Cognitive theory is widely used in design, including: exploring the framework of somatosensory interaction design in museum environment from the perspective of embodied cognition, and proposing a three-level museum user experience interaction design method of body perception layer, behavior control layer and meaning construction layer (Kong, C. et al., 2020) ; Based on the theory of limited cognitive resources and the theory of cognitive schema, this paper studies the generation mechanism of cognitive load in digital interface, and puts forward the interface design strategy related to reducing cognitive load (Wang, H. et al., 2013) . The relationship among usability, user experience and unconscious cognition is analyzed, and the design principles that can satisfy both usability and user experience are put forward: consistency principle, graphic priority principle, timely and effective feedback principle and fluency principle (Xie, W. et al., 2015) , etc. Flow theory (Mihaly, C., 1990) is widely used in product interaction design, which can balance the relationship between challenges and skills, and provide users with continuous and effective feedback to help the iterative development of products. The related research includes: based on the three stages and nine characteristics of flow theory, the user flow experience model of online shopping platform is constructed (Jiang, L. et al., 2018) ; Based on the flow theory, the design method and guiding ideology of Internet products are put forward: providing clear and clear goals, timely and valuable feedback, challenges balanced with skills, smooth operation and comfortable interface (Ou, X. & Tan, H., 2016) ; Based on the three-layer structure, the six principles of flow game interaction design are put forward (Huang, Z., 2017) ; and so on.

2. Typical Application of Design Theory in Product Design

Starting from the innovative design dimension of products and services, scholars at home and abroad have carried out a series of user-centered design studies, and put forward many theories such as usability design, emotional design, experience design and so on. Usability design is mainly composed of easy learning, high efficiency, easy memory, error, satisfaction and so on. Jakob, N.(2004) proposed 10 basic principles for usability design: perceptible system architecture, matching with the real world, freedom and control, continuity and standardization, error prevention, high recognition, flexible and effective use, aesthetics and simplicity, error prompt, help and documentation. Usability design is widely used in product design. For example, through the usability evaluation and modeling of the user interface of the operating system suitable for radiotherapy software, the interface design

elements and usability evaluation and prediction model are established (Jiang, M. et al., 2022). The usability engineering method is introduced into the repeated and periodic product design process, and the usability degree of the product is improved through the usability test experiment (Wang, J., 2006); By obtaining the data indexes such as the effectiveness, the efficiency, the scanning track diagram and the like, and combining the usability problem statistical scale output by the user interview, the evaluation model based on the eye tracking and the usability problem scale is constructed (Li, X. et al., 2018) . Emotional design was first proposed by Donald, N.(2005), which means that product designers, through the study and analysis of people's psychological activities, especially the general rules and principles of emotional generation, purposefully and consciously stimulate people's emotions in product design, so that products can better achieve their purpose of design (Dou, J. & Zhang, F., 2013). The theoretical research on the application of emotional design in product design includes: pointing out the emotional interaction at the form level, content level and behavior level in mobile applications, and exploring the emotional interaction design method based on mobile applications (Sun, X. & Jin, W., 2014) ; Introducing the research methods of emotional design, the research on the differences of customer emotional reactions, and the development status of the application field of emotional design (Gao, W. & Bai, L., 2010); and so on. Xin, X.(2019) constructs four different experience design orientations of user experience design, lifestyle, fashion trend and cultural construction, and analyses the paradigm shift of experience design. Hu, F. & Jiang, M.(2018) discussed the discipline logic of user experience and experience design, and combed the research context of user experience and experience design. Sun, D. et al.(2020) constructed the interactive experience design model of automobile digital interface for elderly drivers, and guided the design practice of automobile digital interface from the aspects of thinking framework, design process and experience level.

3. Research Progress of Interaction Design Theory

Interaction design belongs to the emerging research content of art design discipline. At the level of research elements, Benyon, D. et al.(2005) summarized the elements of interaction design into four elements: People, Activity, Context and Technology, referred to as PACT . Xin, X. (2019) believes that interaction design is composed of five elements: human, action, tool or medium, purpose and scene. At the level of research content, Li, S. believes that product interaction design is a team behavior, and the design team composed of experts with different professional backgrounds, different experiences and different fields is the fundamental guarantee for the success of interaction design. Wu, Q. believes that testing users to use products or product prototypes is an important part of interaction design activities. At the research method level, Alan, C.(2006) created the "Goal-oriented" interaction design

method. The main design tools are personas, goals, and scenarios, as well as common methods such as iteration, prototyping, scenario, and user-centered. At the research level, Wu, Q. believes that interaction design is a process of studying human behavior, and is composed of the information cycle generated between human behavior and products. Qin, J.(2015) puts forward the idea of big interaction design, which transforms the interaction object from small data, non-intelligent entity and virtual body to big data, big wisdom ecological environment.

The construction and development of VSE includes pre-planning, prototype design, interface design, model design, scene building, function realization, test and evaluation, etc. It is a comprehensive, interdisciplinary and multi-field design practice activity, and at the same time, it also needs to consider the needs of users (including perceptual needs, behavioral needs and emotional needs), and on the basis of interaction design research. To achieve the construction goal of student-centered and emphasizing user experience. Therefore, the construction and development of VSE must be guided by the theories and practical experience of psychology and design, grasp the characteristics and needs of students in physiology, psychology, cognition and emotion, and comprehensively use the design principles including timely and effective feedback, balance between skills and challenges, concern for users' emotions, and enhance the unity of interface. In order to effectively improve the construction level, user experience and teaching effectiveness of VSE, we should conduct in-depth research and exploration from the three levels of perceptual interaction, behavioral interaction and emotional interaction, and form a scientific, reasonable and effective interaction design strategy.

Research Methodology

At the same time of theoretical research, the practical development of the VSE project is also carried out. After the completion of the project and the students' test, the user experience evaluation experiment is organized immediately to test the user's overall experience of the VSE case in the sense, behavior and emotion. The interaction design strategy used in the development of VSE is verified to be scientific, reasonable and effective. The experiment was carried out by using Q methodology in behavioral experiments. Q method is a method to measure and study human subjective experience proposed by William Stephenson in 1935 (Brownsr, Q., 1996). It is a combination of qualitative and quantitative research methods, aiming at drawing individual's different views on specific areas, themes or issues. And reveal characteristics within or between individuals in a structured and interpretable manner (Barry, J. & Proops, J., 1999). The procedure for this experiment was based on the work of Dimitrios, S. & David, A.(2011):

1. Obtain the Q population. This Q group mainly comes from three channels: psychology and design theory, user experience needs and evaluation of students after experience. A total of 79 samples were obtained.

2. determine the Q sample. The Q sample refers to the final view selected from the Q population for the experiment. After expert evaluation, 60 Q samples were finally determined, which were distributed in 10 experience dimensions, such as sensory perception, free behavior and active experience.

3. Recruit the P samples. The P sample is the actual respondents who participated in the study and ranked the Q sample (Karimova, M., 2014). P sample size is generally controlled between 20-66, following the principle of small sample size research (Hunter, W., 2011) , taking into account the diversity of schools, gender and so on, 30 undergraduate students majoring in art and design are finally selected to participate in this experiment.

4. Q assignment. Q assignment refers to the process in which P samples evaluate Q samples in time according to their use experience. In order to widen the evaluation gap, this research paper uses 9-level assignment, with the score ranging from -4 to 4, which represents 9 different attitudes towards the Q sample, including complete opposition, very opposition, relatively opposition, basic opposition, neither opposition nor approval, basic approval, relatively approval, very approval and complete approval, and is distributed and collected through the questionnaire star applet.

Results

A total of 30 pieces of feedback data were collected in this experiment, of which 6 pieces of data were missing, 2 pieces of data were unreasonable (the score was not between -4 and 4), and the remaining 22 pieces of data were valid. The average score of each Q sample is shown in Tab.1.

Tab.1 Q samples average scoring results

The dimension of experience	Q sample	Average score
Sensory Perception	I feel a sense of technology.	3.59
	I really like the fact that there are multiple sound settings that make me feel like I'm there.	3.41
	I feel a strong sense of reality.	3.18
	The model is very realistic, and I feel that it is no different from the real one.	3.27

	The sound of equipment operation makes me feel real.	3.45
	I feel the scene design is very exquisite.	3.27
	I think the color matching is very reasonable, and the eyes are not tired.	3.59
	I think the interface is exquisite.	3.41
	All kinds of icons have obvious meanings, and I can understand the functions without thinking.	3.45
	I think information reading is very easy.	3.36
	I can find the operating instructions quickly.	3.41
	I think the layout is unified and standardized, and it's easy to find the information you want.	3.64
Free Behavior	I can undo and redo at will.	3.45
	The operation steps of each link are not many, and I can easily complete various tasks.	3.50
	I can jump to different modules to learn at will.	3.68
	My learning progress will be constantly changing, so that I can see my growth.	3.45
	I like this form of automatic generation of experimental reports.	3.50
Convenient Control	Set up a variety of drone control modes, I feel very flexible and efficient.	3.55
	I feel that the control is very convenient and realistic.	3.55
	The change of the rocker model gives me a stronger sense of experience.	3.55
Timely Feedback	I can do whatever I want, and the system can fix my mistakes.	3.36
	I can learn easily, and the system provides a variety of forms of help.	3.41
	I feel that the feedback is timely and in place.	3.45
	The experiment report is very detailed, and I can clearly see where and why I made mistakes.	3.32

A Clear Goal	I know exactly what I'm going to do.	3.41
	I can do what I want.	3.41
	I'm glad to see the results right away.	3.55
A Sense of Control	I can fly the drone freely.	3.55
	I have complete control of the aerial camera operation.	3.50
	I think the parameter setting is very flexible.	3.55
	I can switch my perspective at will.	3.64
	I can see where I am right now.	3.73
	I feel that my study is going well.	3.50
	I feel like I'm actually shooting.	3.45
	I feel that my consciousness and behavior are consistent.	3.59
	All the interface layout and operation specifications are unified, and I can easily control them.	3.64
Emotional care	I feel that the text message is very warm.	3.36
	I like the feedback information with the stem.	3.50
	I think my emotions are taken care of.	3.55
	Can carry on the simulation examination, lets my heart not panic.	3.64
Balance of Challenge and Skill	I feel that the difficulty of the experience is appropriate.	3.50
	I like the design idea of gradually increasing the difficulty.	3.55
	There are not many operational steps in each stage, so I can easily complete various tasks	3.59
	I feel that I can complete the experience through hard work.	3.64
	I like the fact that I can choose tasks of different difficulty at will.	3.59
Forget Me	I felt that my experience was very short, but it actually took a long time.	3.23
	The experience was longer than I expected.	2.82
	I didn't notice the passage of time.	3.32

	I was not disturbed in any way.	3.32
	I'm focused on my studies.	3.50
	I have a high concentration.	3.36
	I feel that the design is very careful.	3.73
	I feel the operation is very smooth.	3.50
	I think the virtual world I'm in is the same as the implementation.	3.32
	I did learn something.	3.64
Active Experience	While challenging, I would love to participate.	3.73
	It is easy to use and can be operated normally without special training	3.73
	I like this form of learning very much.	3.68
	I also want to experience a similar VSE.	3.64
	I want to learn more about aerial videography.	3.64

Discussion

The results of the user experience evaluation experiment show that in the dimension of "sensory experience", the average score of 11 Q samples is more than 3, and the comprehensive average score is 3. 42, which indicates that the subjects are very satisfied with the user experience at the sensory level, and they agree with the interaction design strategies adopted by the VSE cases in the aspects of situation simulation, atmosphere rendering, information readability and aesthetic enjoyment.

From the five dimensions of "free behavior", "convenient manipulation", "timely feedback", "clear goals" and "sense of control", most of the Q samples got a high score of more than 3.50, with a comprehensive average score of 3.51, especially in the dimension of "sense of control", with an average score of 3.57. It shows that the students can operate the experiment well in the process of the experiment, which really realizes the substitution value of the VSE, and also proves that the behavior interaction design strategy adopted in the development process of the experimental case has achieved success.

In the four experience dimensions of "balance between challenge and skill", "emotional care", "selflessness" and "active experience", the subjects were also very satisfied with the user experience, with a comprehensive average score of 3.50, and the average score of the "active experience" dimension was as high as 3.62, indicating that the test made the students interested in the VSE. The willingness to continue similar experiments is very strong,

which also shows that the emotional interaction design strategy adopted in the development process of this experimental case is very effective.

In addition, from the perspective of P samples, the individual average score of 22 valid P samples is also very high (as shown in Fig.7), and the comprehensive average score reaches 3.49, which indicates that the overall experience of students in this VSE is very good, and proves that the interaction design strategy adopted in the development process of this VSE case is scientific, reasonable and effective.

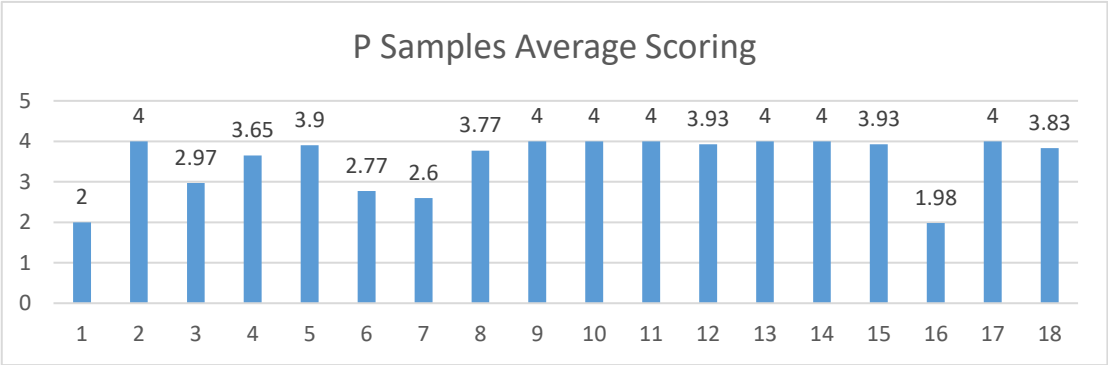

Fig.7 Personal average score data for sample P

Conclusion

Under the guidance of psychology and design theory, this research paper draws on the theories and practical experience of a large number of product design related literature, combines with the development practice of VSE cases, explores and studies the interaction design strategies of VSE in the aspects of perception, behavior and emotion, and tests the user satisfaction through the user experience evaluation experiment. It has won the general praise of the students. The interaction design strategy and development model of VSE are summarized as follows:

1. Perceptual interaction design strategies of VSE

(1) Style should be adapted. The style must conform to the user's subject characteristics and specific experimental content, create a visual presentation that meets the user's psychological expectations, and better help users immerse in the virtual experimental environment.

(2) Design should be simple. The excessive complexity and confusion of the interface should be avoided, the convenience of information acquisition should be maintained, and the visual fatigue of users should be reduced.

(3) Navigation should be convenient. Navigation convenience. Navigation needs to be simple and intuitive, and it is recommended to be placed at the top of the interface.

(4) Colors should be harmonious. Design appropriate color scheme and contrast selection to ensure the readability and visibility of the interface and reduce the visual stimulation of color.

(5) Elements should be unified. Maintain the harmony and unity of visual presentation, help users quickly understand the function and layout of the interface, and reduce the burden of user memory.

(6) Information should be readable. Reduce user cognitive consumption, improve learning efficiency and use experience.

(7) Scene should be simulated. Strive to create a virtual reality experimental environment.

(8) Design should be interesting. The design should arouse the user's sense of novelty and excitement, enhance the user's sensory excitement, and enrich the visual effect.

2. Behavioral interaction design strategies of VSE

(1) Ensure the realism of the experiment. To restore the real experimental operation including process, steps and operation forms to the maximum extent.

(2) Set explicit guidance information. Balance user skills with the challenges of using product features to help students successfully complete specific lab tasks or operational processes.

(3) Provide clear targeted feedback. Feedback information should be comprehensive and detailed, concise, timely and accurate.

(4) Maintain system availability. Allow users to make mistakes or unexpected situations, ensure data security, and take targeted preventive or treatment measures.

(5) Keep the system operational. Simple and flexible operation forms are set to make the system easy to operate and interact.

(6) Keep the system visibility. Ensure that the user understands the current state of the process and operations to avoid confusion and uncertainty.

(7) Keep the system flexibility. Enhance students' sense of control over the experiment.

(8) Keep the system open. Ensure that students can carry out experiments anytime and anywhere, and strive to provide a variety of experimental operation forms to stimulate students' creativity and imagination.

3. Emotional interaction design strategies of VSE

(1) Find out the characteristics of user groups. Understand user values, motivations, and emotional States to ensure that the experimental project meets user expectations.

(2) Ensure that users quickly grasp the use of methods. The system should be easy to learn and use, and provide a variety of help measures to alleviate students' anxiety.

(3) Reduce the difficulty of the experiment. Organic disassembly of experimental content, set up simulated examination links and help assistants to enhance students' confidence in learning.

(4) Ensure the fluency of the experiment. Take a variety of measures to improve the fluency of the experiment and reduce the user's irritability.

(5) Create emotional resonance. Help users establish emotional connections and enhance their identification with products or services.

(6) Provide emotional support. Provide emotional support and positive feedback to reduce depression.

According to the summary of the above interaction strategies, combined with the determination of user needs and user experience dimensions, as well as the construction requirements of different levels of VSE, this research paper proposes an interaction design and development model of VSE (as shown in Figure 8) for reference by relevant development teams and research teams.

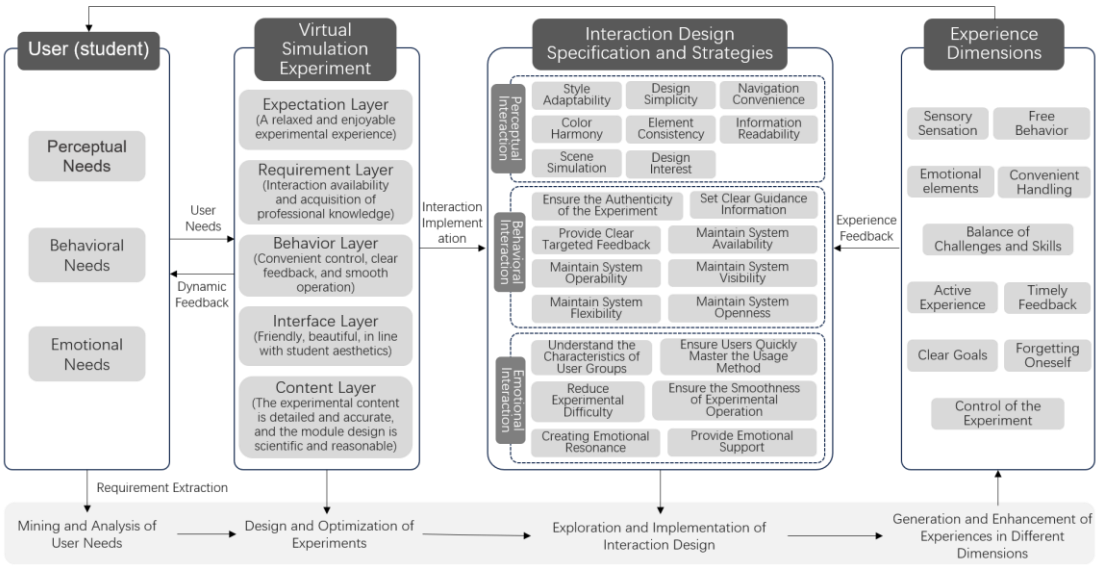

Fig.8 Interactive design and development model for VSE

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