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A Comparative Study of virtual Reality Combined with Eye Movement Measurement in the Design Teaching Process

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Abstract: - The integration of virtual reality (VR) and eye-tracking technologies in the design teaching process is introduced in this research. Additionally, the effectiveness of the teaching application is assessed using the ARCS and IMMS evaluation models. The conventional design education method is compared and improved in this article, which benefits not only the effectiveness of individual designs but also the productivity of the entire industry. This multidisciplinary study, which has significant academic and practical value, offers a theoretical and technical foundation for using and evaluating immersive design in various fields.

Keywords: immersive design; pedagogical evaluation; virtual reality

I. INTRODUCTION

This study aims to integrate new technologies to design instruction for undergraduate programs, utilizing digital approaches to maximize teaching efficacy and conduct assessments. The latest information technology revolution has dramatically altered the vehicle and connotation of education, particularly in design art. The traditional method of teaching design art involves students primarily listening to classroom lectures, watching classroom demonstrations, employing textbooks, and designing software courses as learning tools.

As the share of technical products and network applications in education rises, it has contributed to reforming educational conceptions and instructional strategies. Virtual Reality (VR) is a new computer-assisted teaching system widely used in the leisure and entertainment industries. Students can engage in the act of learning in an immersive environment with the aid of virtual reality equipment, completing activities such as experiencing, knowing, comprehending, assessing, and memorizing. The VR teaching model uses multimedia technology to create virtual classrooms, laboratories, and communities that are important parts of the teaching and learning environment. (Liu et al., 2019) explore the technological challenges in system building and function configuration, with data collecting and good modeling as the central difficulty of construction. Currently, virtual reality technology is a hot topic in education, which promotes the informatization of education in China.[1] Fu (2021) evaluates the deployment pathways and effects of VR technology in information education.[2] Computer-aided design techniques create virtual human models , and attire (Hu, 2021). [3] Xue et al. (2021) present an in-depth investigation and analysis of the execution of English listening instruction utilizing virtual environments technology. [4] Moro et al. (2021) applied a meta-analytic method to evaluate the influence of VR or AR on preclinical physiology and anatomy students' knowledge acquisition. [5].

Immersive virtual environments aid Design students in creating prototypes, conducting research, exploring, and gaining experience in a steady design process. With the development of metaverse-related supporting technologies, virtual reality and mixed reality technologies have entered the testing phase for commercial application, and the associated platforms are becoming open-sourced gradually. Using VR technology, numerous psychological experiments and assessments have been undertaken [6]. In terms of experimental process control, variable introduction, scene and behavior reproduction, and ecological sustainability, the use of interactive virtual environments to conduct relevant psychological studies has numerous advantages. However, the use of mixed reality technologies such as VR glasses and the experimenter's possible difficulty focusing while in an immersive

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environment are experimental limitations that must be overlooked. Psychologists use cross-sectional research to mimic disease, ethics, and experimental design in virtual reality scenarios [7]. Pan et al. recognized the most incredible difficulty of creating a fully interactive avatar capable of passing the VR+Turing test, which involves the collaboration of psychologists, VR technologists. The study group of Araiza Paola at Swinburn University: Cognitive and emotional effects of an immersive virtual reality encounter on youngsters. Using a comparison method, 70 children between the ages of 6 and 7.9 were selected to view the fairy tale in three different formats: an immersive headset, a 2D movie, and a paper storybook. Later interviews with the three groups of children revealed that the content delivered in the immersive environment had the most significant impact on children [8]. According to Marn-Morales (2018), affective computing has become an important topic of psychology as well as interdisciplinary study, and the goal is to design a system that can recognize emotions automatically.

Most research has been conducted in non-immersive environments [9]. This project aims to create a system for recognizing emotional states based on immersive virtual worlds. As outlined in each quadrant of the Circumplex Model of Affects (CMA), four potential virtual situations were created to induce four distinct combinations of arousal and evaluation. Sixty participants' electroencephalograms (EEG) and electrocardiograms (ECG) were recorded during the study experiment. These numbers quantify linear and nonlinear brain and cardiovascular dynamics, whilst the dynamics are fed into a SVM to predict the subjects' evaluation judgments. The precision of the arousal dimension of the model was 75%, whereas the accuracy of the assessment dimension was 71%. Based on brain and cardiac dynamics, the experimental results confirmed the application value of virtual environments that can generate and automatically discern between distinct emotional states; the study's findings can be used in numerous disciplines, including architecture, health, education, and video games. This work combines ingeniously the quantitative research methodologies of electroencephalography (EEG) and electrocardiography (ECG) in ergonomics with a fully immersive audiovisual experimental setting in virtual reality to test audiences, providing an excellent cross-disciplinary perspective. The interference factors of the experimental wearer on the subjects were not included in the impact weights, and it is known that the weight of the VR helmet at this stage has produced certain pressure and constraint on the head. Whether the accuracy of EEG acquisition under the VR helmet can be maintained as stable and accurate as, in reality, becomes the most excellent issue. The method's greatest challenge is whether the precision of EEG acquisition when using a virtual reality (VR) headset can be maintained at the same level of stability as in the actual world—using mathematical algorithms that do "point-of-view rendering," other recent research endeavors to forecast customers' interest in things in real-time. Researchers have created an innovative data-driven eye-head coordination model that can anticipate users' gaze positions in real-time without using eye trackers or external hardware [10].

Currently, evaluative research on immersive teaching and learning utilizing virtual reality in conjunction with ergonomic research methodologies is a plausible and realizable direction of study. With the continued progression of VR technology and equipment, the area of applicability and precision of evaluation methodologies will increase. Stoji et al. (2018) reviewed the virtual reality (VR) applications in education (with a focus on evaluation criteria), and the results of a small qualitative research performed with teachers in the Republic of Serbia who are all familiar with VR as teaching tool.[11] The primary objective of (Veronez, 2018) was to assess the application value of a cheap immersive driving simulator to enhance the teaching-learning process of Transport Infrastructure.[12] The results may be valuable for educators and researchers interested in the construction of comparable virtual classrooms (Yebra, 2018).[13] The VR Multisensory Classroom (VRMC) is envisioned by Edwards et al. (2019) within a VR head-mounted display, in which students use hand movements to construct hydrocarbon molecules with the Leap Motion system. [14] (Bergl et al., 2020) examine 72 faculty comments on fellows' end-of-rotation evaluations, of which 22 were made postintervention.[15] The (Gao, 2021) encompasses fundamental technologies, the equipment environment, content resources, digital cloud. [16] The aim of (Kuhn et al., 2021) was the conceptual design of a newly established learning/teaching paradigm for the digital transformation, with a particular emphasis on the impact of surgical instruction.[17] In 2017, a VR laboratory with 26 Oculus Rift headsets was established (Marks, 2021). [18] In a famous institution, the soft systems methodology (SSM) was used to examine how students' performance in a radio frequency identification (RFID) course using mixed reality technology evolved over time. (Wu, 2021) [19].

This paper proposes an approach for immersive design education based on previous teaching experience. Comparing the outcomes of two concurrent training programs, we examine the effect of adopting an immersive learning environment in garment design. Using the ARCS and IMMS assessment models, the influence on individual students was investigated further in order to correct the deficiencies of the immersion training process in term of actual implementation scenario. The entire teaching and learning process was subsequently enhanced by repeated revisions.

II. The Collection of Research Materials and the Design and Production of Immersive Virtual Resource Scenes

Before completing this study, the research team created a library of virtual simulation clothing materials that might be used in future comparative teaching studies by combining historical data. It is an independent, open, and continuously expanding database. The authors collaborated with researchers from multiple countries and regions to analyze and find representative clothing and apparel samples for 3D scanning and virtual simulation through statistical cluster analysis, which was optimized by 3D software and integrated into a platform repository for teaching and research using Unity. Based on the research need to create immersive scenes with replaceable materials (Figure 1,2), as the design course varies with the participants and training topics, full immersive teachin.

Figure 1. Virtual repository loading procedure (image from the screenshot of the virtual platform designed by the research team).

Figure 2. Virtual featured clothing details display (designed by the research team members - 3D Chinese Qing Dynasty virtual clothing).

III. The Creation of Eye-tracking Feedback and Immersive Scenario-based Teaching Processes

The study employed a cross-sectional comparative technique using concurrent dual teaching processes. The average age and ratio of male to female students in both groups should be comparable.

In the first group, the traditional way of instruction was used, from inspiration through the design of clothing samples to the submission of final designs, all of which occurred in the actual classroom. Participants utilized standard eye-tracking technologies to collect user ergonomics-related physiological data and examine their interest points and feedback. At the same time, they viewed a sample photograph on a desktop computer.

In the other group, the same number of participants used the immersive environment teaching method, where the inspiration for the proposition material was a virtual simulation sample modeling. The medium was HTC Vive virtual glasses. The participants use the eye-tracking recording and analysis plug-in embedded in the VR glasses. to collect and analyze physiological data and then computer-related software to create a quick sample and import it into the immunization database. After analyzing their physiological indicators to determine the user's experience and appraisal of the samples, they were corrected on the computer and manufactured in kind.

Figure 3. Eye movement data of participants tested by eye-tracking device in traditional training: eye trajectory, area of interest, focus heat map.

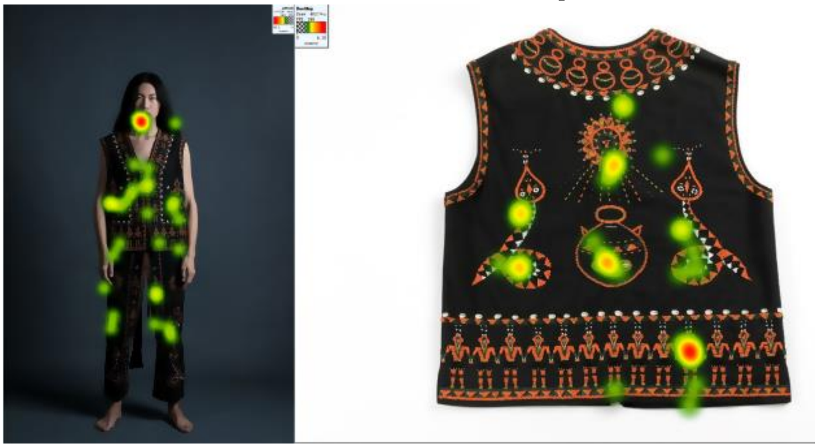

Figure 4. Eye movement data of participants in traditional teaching process.

Figures 3 and 4 indicate that the typical desktop eye-tracking equipment can help design students perform user physiological feedback data studies to evaluate the communication rates and attractiveness of designs. However, desktop eye movement analysis methods for flat patterns have limitations, particularly in fashion design, where the audience's visual interest may be vastly different when viewing products that emphasize silhouettes and overall three-dimensional shapes, such as clothing and apparel, as opposed to when viewing two-dimensional images. If significant objects, such as the model's face and body, are present, they will influence the user and divert their attention, resulting in skewed analysis results. In VR situations, however, the pupils' watching mode changes to a free interactive form. This sort of study analyzes eye movements in both viewing modes by simplifying the scenic surroundings, minimizing distracting features (Figure 5), and monitoring students' eye movement indices in various circumstances (Figure 6).

Figure 5. Simplified version of the virtual display scene inspired by clothing source material.

Figure 6. Immersion group watching and discussing the scene.

IV. SANFUZZY EVALUATION COMBINED WITH IMMS MODEL TO CROSS-SECTIONALLY COMPARE THE EFFECTIVENESS OF TWO GROUPS OF LEARNING

A. Fuzzy Evaluation Analysis Method

First, we identified and extracted the multi-level factors of the influencing factors of the teaching process using virtual design through literature research, expert questionnaire, and fieldwork. Twenty core evaluation factors were summarized according to the frequency of occurrence and other factors.

Among various analysis and evaluation methods dominated by human subjective perception, Analytic Hierarchy Process (AHP) has high superiority. It can make practical judgments and decisions on many uncertain qualitative problems that are difficult to analyze quantitatively. However, in the calculation process of the traditional hierarchical analysis method, there is less subjectivity in the method of constructing the judgment matrix considering the judgment of decision-makers. The consistency test against the matrix is more complicated, while the scientificity and rationality of the judgment rules are also controversial. In order to solve the consistency judgment problem, researchers have combined the fuzzy consistency matrix in fuzzy mathematical theory and the hierarchical analysis method to develop the fuzzy hierarchical analysis method, which can better solve the subjective decision judgment of people on related evaluation problems.

According to the hierarchical analysis method, the evaluation indexes includes three layers. The first layer is the target layer the influencing factors of the virtual teaching process. The second layer is the criterion layer: Attention, Satisfaction, Confidence, and Relevance. The third level is the criteria layer of sub-indicators, and Attention sub-levels include Inquiry, Humor, Variability, Participation, Concreteness, Attention; Satisfaction sub-levels include Scheduling, Positive outcomes, Unexpected Rewards, Natural Consequences and Avoid Negative Influences; Confidence sub-levels include Learning Requirements, Self-confidence, Expectations, Attributions and Difficulty; Relevance sub-levels include Immediate applicability, Future usefulness, Need Matching, Modeling Choice. The hierarchical analysis model based on the FAHP method is shown in Figure 7.

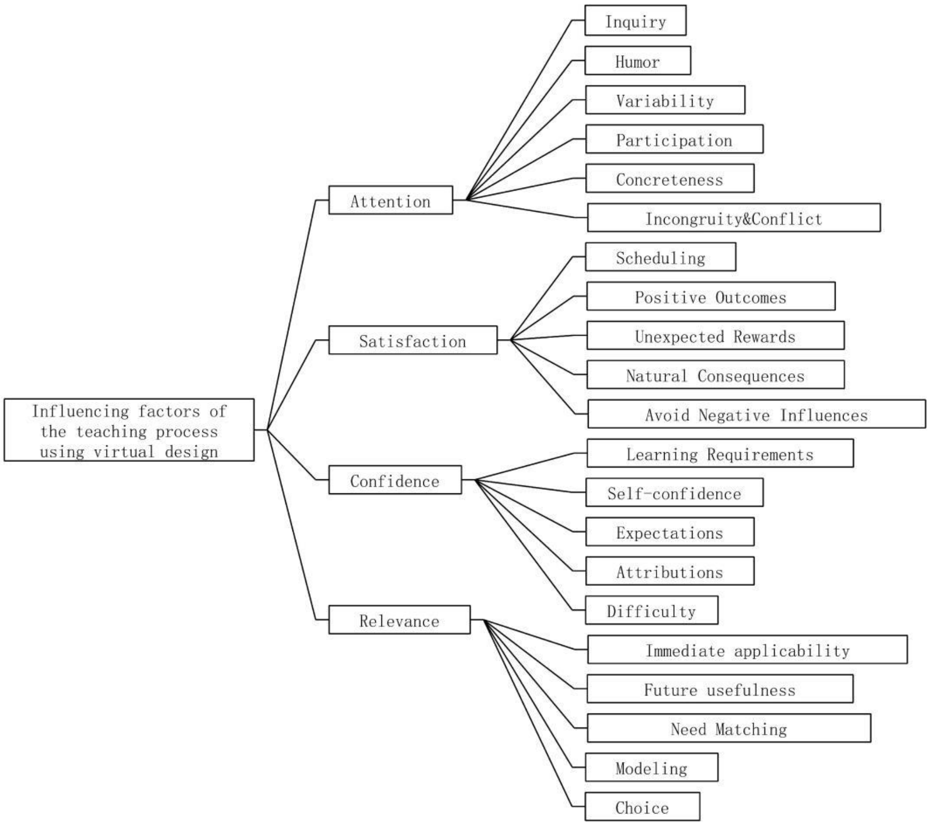

Figure 7. Hierarchical analysis model based on the FAHP method.

1) *Mathematical Theorem of Fuzzy Matrix*

Define the n-dimensional square matrix R:

$$R = \left(r_{ij}\right)_{n\times n} = \begin{bmatrix} r_{11}\ r_{12} \cdots r_{1n} \\ r_{21}\, r_{22} \cdots r_{2n} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \\ r_{n1}\ r_{n2} \cdots r_{nn} \end{bmatrix} \tag{1}$$

1) If the matrix R satisfies 0≤rij≤l,(i,j=1,2,⋯,n), then R is a fuzzy matrix.

2) If the matrix R satisfies condition 1 and $r_{ij}+r_{ji}=l$, (ij=1,2,⋯,n), then R is a fuzzy complementary matrix.

3) If the matrix R satisfies conditions 1 and 2, and $r_{ii}=0.5$,(i=1,2..n);$r_{ii}=r_{ik}-r_{jk}+0.5$,(i,j,k=1,2,⋯,n)

Then, R is called the consistent fuzzy matrix.

2) *Calculation Steps of Fuzzy Hierarchical Analysis Method*

1) Fuzzy hierarchical analysis method score table

A paired comparison of the factors is specified.

0.1: factor i is absolutely less important compared to j.

0.2: factor i is very unimportant compared to j.

0.3: factor i is relatively unimportant compared to j.

0.4: factor i is slightly less important compared to j.

0.5: factor i is equally important compared to j.

0.6: factor i is slightly more important compared to j.

0.7: factor i is more important compared to j.

0.8: factor i is very important compared to j.

0.9: factor i is absolutely more important compared to j.

2) Establishmentof fuzzy hierarchical analysis scoring matrix

The fuzzy hierarchical analysis scoring matrix A was obtained using the 0.1~0.9 scaling method described above to compare two by two for each evaluation factor.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (2)$$

The matrix A meets the provisions of the fuzzy complementary matrix, i.e., 0<aij<1; aij+aji=1; aij=0.5,(i=j).

3) Sum the matrix A by rows

$$\mathrm{a_i} = \sum_{k=1}^{\mathrm{n}} a_{ik}, (i,k=1,2\cdots n) \quad (3)$$

4) Determine the weight determinant WI.

$$w_i = \frac{1}{n} - \frac{1}{2a} + \frac{ai}{na} \quad (4)$$

$$WI = \begin{bmatrix} W1 & W2 & \cdots & Wn \end{bmatrix}^T \quad (5)$$

In formula

$$\alpha = \frac{\mathrm{n\text{-}1}}{2} \quad (6)$$

5) Consistency CI test

Construct the weight matrix W

$$\mathrm{w_{ij}} = \alpha\left(\mathrm{w_i} - \mathrm{w_j}\right) + 0.5 \quad (7)$$

$$W = \begin{bmatrix} w11 & w12 & \cdots & w1n \\ w21 & w22 & \cdots & w2n \\ \ddots & \ddots & \ddots & \ddots \\ wn1 & wn2 & \cdots & wnn \end{bmatrix} \quad (8)$$

$$CIA,W = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|w_{ij} - \alpha_{ij}\right|}{n^2} \quad (9)$$

The CI value is inverse correlated with the consistency, and the general convention is that a CI<0.1 reflecting the consistency requirements are met.

B. Modification Matrix with Particle Swarm Optimization (PSO)

Due to the intense subjectivity of expert scoring in the process of fuzzy hierarchical analysis, the scoring matrix is often inconsistent or omitted, and then we can use the particle swarm optimization algorithm to correct thescoring matrix.

When solving problems based on particle swarm optimization (PSO), each feasible solution corresponds to a "particle" in space, and continuous iterative search is carried out based on certain rules until the particle with the largest fitness is obtained. All particles define a position vector (particle position) and a velocity vector (determine the next flight state). Use the objective function to calculate the fitness of the particle's current position. This parameter can be seen as the distance between the particle and the target value. In each iterative search process, the particles in the population will adjust the state by referring to their historical position, and also learn the optimal solution of the population. On this basis, the next flight direction and speed related parameters will be adjusted until the global optimal solution is determined, and then the parameters of the maximum fitness particles will be output.

The bird is abstracted as a particle (point) without mass and volume. The position of particle I is denoted as vector Xi, and the velocity of flight is denoted as vector Vi. The fitness of each particle can be calculated through the objective function, and the historical best position (pbest) and current position Xi of the particle can also be obtained. These parameters can be regarded as the flight experience of the particle, which can provide support for particle optimization. In the process of searching for particles, the current group best position (gbest) is determined, and particles can also learn this parameter to adjust their own state; When the particle moves next time, it controls its flight speed and direction according to its own and group optimal solution, so as to improve its fitness.

When PSO initializes, it needs to set a group of random particles (random solutions), and then iterate to find the optimal solution under certain rules. In each iteration, particles refer to local and global optimal solutions to optimize and adjust their own parameters. When particles update their velocity and position parameters, the corresponding formula is as follows.

$$v_{i+1} = v_i + c_1 \times \mathrm{rand}(0 \sim 1) \times (\mathrm{pbest}_i - x_i) + c_2 \times \mathrm{rand}(0 \sim 1) \times (\mathrm{gbest}_i - x_i) \tag{10}$$

$$X_{i+1} = X_i + V_i \tag{11}$$

In which M represents the particles number in the population; Vi refer to the particle velocity; pbest means individual optimum; gbest denotes the global optimum; rand(0~1) is a random number between (0, 1); Xi means present position. c1 and c2 represent the learning parameters, mostly, c1 = c2 = 2.The particle has a maximum limiting velocity of Vmax.Under condition of the velocity higher than the set Vmax, the velocity is limited to Vmax.

C. Optimized and adjusted concluding data

1) Expert Group Decision Data

After determining the the influencing factors of the teaching process using virtual design and analysis model, the generated questionnaire was transformed into an online form (Figure 8), 12 experts in clothing design and engineering were selected from the expert database, and 30 participants from the previous design experiment were selected for the online questionnaire. A total of 42 valid questionnaires were finally recovered.

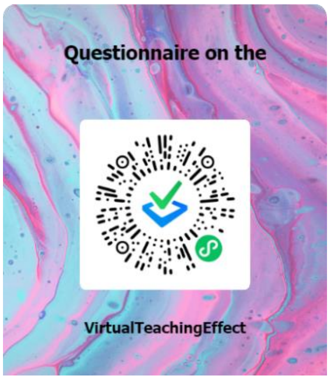

Figure 8. Questionnaire form generated by Tencent Questionnaire Online.

2) Group Decision Data

The fuzzy hierarchical evaluation is based on valid expert and antecedent user questionnaires.

First, the criterion level weight matrix is calculated.

1)Matrix for calculation A=(aij)$_{4x4}$:

0.5	0.4914	0.5062	0.5147
0.5086	0.5	0.5131	0.5226
0.4938	0.4869	0.5	0.5064
0.4853	0.4774	0.4936	0.5

2)Matrix dimension n:

n=4

The determinant A1 of the summation by rows according to matrix A.

A1T=(ai)4x1=[2.0123 2.0442 1.9871 1.9564]

3)Determine weight value of every factor WI

α=(n-1)/2=1.5

$$w_i = \frac{1}{n} - \frac{1}{2a} + \frac{ai}{na} \tag{12}$$

WIT=(wi)4x1=[0.2521 0.2574 0.2478 0.2427]

4)Construct the weight matrix W

$$\mathrm{w}_{ij} = \alpha\left(\mathrm{w}_i - \mathrm{w}_j\right) + 0.5 \tag{13}$$

0.5	0.492	0.5063	0.514
0.508	0.5	0.5143	0.522
0.4937	0.4857	0.5	0.5077

0.486	0.478	0.4923	0.5

5)Calculate the consistency of CI

$$CIA,W = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|w_{ij}-\alpha_{ij}\right|}{n^2} = 0.0006$$

Original weight matrix: Influencing factors of the teaching process using virtual design Attention: consistency CI = 0.0426, Original weight table of Intermediate layer can be seen in Table 1.

Table 1. Original weight table of Intermediate layer.

	Inquiry	**Humor**	**Variability**	**Participation**	**Concreteness**	**Incongruity&Conflict**
Inquiry	0.5	0.4843	0.4991	0.479	0.4916	0.5154
Humor	0.5157	0.5	0.5135	0.4934	0.5069	0.5286
Variability	0.5009	0.4865	0.5	0.4789	0.4935	0.5135
Participation	0.521	0.5066	0.5211	0.5	0.5144	0.5353
Concreteness	0.5084	0.4931	0.5065	0.4856	0.5	0.5212
Incongruity& Conflict	0.4846	0.4714	0.4865	0.4647	0.4788	0.5

Corrected weight matrix for calculation: Influencing factors of the teaching process using virtual design Attention :consistency CI = 0.0004. Corrected weight table of Intermediate layer can be seen in Table 2.

Table 2. Corrected weight table of Intermediate layer.

	Inquiry	**Humor**	**Variability**	**Participation**	**Concreteness**	**Incongruity&Conflict**	**Weights (wi)**
Inquiry	0.5	0.4843	0.4991	0.479	0.4916	0.5154	0.1646
Humor	0.5157	0.5	0.5135	0.4934	0.5069	0.5286	0.1705
Variability	0.5009	0.4865	0.5	0.4789	0.4935	0.5135	0.1649
Participation	0.521	0.5066	0.5211	0.5	0.5144	0.5353	0.1732
Concreteness	0.5084	0.4931	0.5065	0.4856	0.5	0.5212	0.1676
Incongruity&Conflict	0.4846	0.4714	0.4865	0.4647	0.4788	0.5	0.1591

Then the criterion-level weight matrices for the sub-indicators were calculated similarly and corrected for consistency, for example, for functional modules.

Original weight matrix: Influencing factors of the teaching process using virtual design: Attention: consistency CI=0.0182. Original weight table of functional modules layer can be seen in Table 3.

Table 3. Original weight table of functional modules layer.

	Inquiry	**Humor**	**Variability**	**Participation**	**Concreteness**	**Incongruity&Conflict**
Inquiry	0.5	0.4843	0.4991	0.479	0.4916	0.5154
Humor	0.5157	0.5	0.5135	0.4934	0.5069	0.5286
Variability	0.5009	0.4865	0.5	0.4789	0.4935	0.5135
Participation	0.521	0.5066	0.5211	0.5	0.5144	0.5353
Concreteness	0.5084	0.4931	0.5065	0.4856	0.5	0.5212
Incongruity& Conflict	0.4846	0.4714	0.4865	0.4647	0.4788	0.5

Corrected weight matrix for calculation: Influencing factors of the teaching process using virtual design: Attention: consistency CI=0.0004. Corrected weight table of functional modules layer can be seen in Table 4.

Table 4. Corrected weight table of functional modules layer.

	Inquiry	**Humor**	**Variability**	**Participation**	**Concreteness**	**Incongruity&Conflict**	**Weights (wi)**
Inquiry	0.5	0.4843	0.4991	0.479	0.4916	0.5154	0.1646
Humor	0.5157	0.5	0.5135	0.4934	0.5069	0.5286	0.1705
Variability	0.5009	0.4865	0.5	0.4789	0.4935	0.5135	0.1649
Participation	0.521	0.5066	0.5211	0.5	0.5144	0.5353	0.1732
Concreteness	0.5084	0.4931	0.5065	0.4856	0.5	0.5212	0.1676
Incongruity&Conflict	0.4846	0.4714	0.4865	0.4647	0.4788	0.5	0.1591

Ultimately, the research group came up with a table of intermediate and bottom-level findings (weights) for group decision-making. The summary table of the conclusions (weights) of the middle and bottom layers of the group decision, as shown in table 5.

Table 5. Corrected weight table of Intermediate layer.

Bottom element	Conclusion value (overall weight)	Peer weight	Upper level
Inquiry	0.0415	0.1646	Attention
Humor	0.043	0.1705	
Variability	0.0416	0.1649	
Participation	0.0437	0.1732	
Concreteness	0.0423	0.1676	
Incongruity&Conflict	0.0401	0.1591	
Scheduling	0.0523	0.2033	Satisfaction
Positive Outcomes	0.0515	0.2002	
Unexpected Rewards	0.0515	0.2	
Natural Consequences	0.0515	0.2001	
Avoid Negative Influences	0.0506	0.1965	
Learning Requirements	0.0502	0.2025	Confidence
Self-confidence	0.0503	0.2031	
Expectations	0.0512	0.2064	
Attributions	0.0494	0.1994	
Difficulty	0.0467	0.1886	
Immediate applicability	0.0476	0.1961	Relevance
Future usefulness	0.0495	0.2038	
Need Matching	0.0511	0.2107	
Modeling	0.046	0.1894	
Choice	0.0486	0.2	

V. DISCUSSION

Following the group design phase, the IMMS (Instructional Materials Motivation Survey) technique was utilized to evaluate the success of the two groups' motivation to develop the instructional process. As design aspects, we leveraged relevancy, confidence, and satisfaction. Following the instruction, a total of 21 questions were designed to evaluate students' perspectives on ARCS. In addition, these survey questions, which are based on instructions such as "attention," "satisfaction," "confidence," and "relevance," have been divided into numerous groups. Since respondents' evaluations of the aforementioned four characteristics are frequently vague and difficult to evaluate, the group decided to use the fuzzy hierarchy approach to establish the final data of the two groups and conduct a comparative analysis.

After accumulating and analyzing the outcomes of a system evaluation, the upper limits of the four fuzzy scales were utilized to compare the teaching and learning processes of the two groups. Using the IMMS evaluation scale, the evaluation of overall efficacy was undertaken. Extremely high or extremely low assessment indices show that the teaching process is not appropriate for enhancing the efficacy of design education. On the basis of the final assessment indices, the two separate instructional approaches are reviewed and improved. The fuzzy test reveals that the immersive apparel design executive group fosters student involvement (learning positive index of 3.5, moderate). However, it does not overly stimulate the interest and motivation of designers, consequently impacting students' concentration during the design process, and has produced a positive feedback effect.

VI. CONCLUSIONS

In this study, the critical technologies associated with the design process based on immersive environments are analyzed in depth.

(1) The authors present and optimize a novel technique for producing virtual reality (VR) sceneries for the design sector. Initial 3D scanning technology is integrated with 3D modeling and virtual simulation software, such as 3D Max and Unity. So the process from design to prototype is optimized, design efficiency is increased, and the design process is sped up.

(2) It is proposed to use VR and eye-tracking technologies in design education and training. The researchers incorporated 120-380 Hz eye tracking technology into the HTC Vive VR glasses, giving localized tracking of the head and hands, overcoming the constraints of ordinary monitors, and concluded that immersive design functions closer to a genuine perspective. These two kind of technologies contribute to the development of an immersive testing environment. In this context, participants' natural cognition and perception, as well as correct experimental data, are collected, ensuring the capture of quantitative data and precise experiment feedback. In an immersive environment, eye-tracking supply precise information for monitoring the responses of test subjects. The immersive,

engaging environment generated by VR technology enhances the viewing experience of such technology, hence driving the advancement of eye-tracking assessment technology. It demonstrates the advantageous interdisciplinarity between design and ergonomics and supports utilization.

This strategy is particularly advantageous for international student or designer communication throughout design school. It does not need the use of spoken language for communication because it enables the direct detection of eye movement data in an immersive space, hence eliminating biases and inaccuracies.

To assess the success of design and the learning process, a novel inter-disciplinary approach is utilized. integrating two kind of assess techniques The ARCS motivation assessment model was applied to determine the motivation ratings and self-efficacy enhancement indices of students (designers), while the IMMS scale kept these enhancement indices within acceptable levels. Using the IMMS assessment scale and ARCS model, a comparison between a standard design process and an immersive design process was made. A fuzzy algorithm was used to evaluate students' (and designers') confidence in using VR equipment, i.e., the feeling of achievement at the end of the design process, and the sense of connectedness to design process throughout the process.

The study's flaws and prognosis are discussed.

(1) Due to the limitations of technology and the actual teaching process, VR immersion scene teaching is limited to the design process and learning effectiveness comparison. Future research can introduce multiple course linkages, integrate clothing virtualization design (virtual simulation software like CLO 3D), textile and garment 3D scanning, and other pre-courses to form a curriculum group for in-depth research and evaluation.

(2) The instructional cases in this research need more depth. Later, we will develop and organize a virtual costume resource library with additional characteristics and documentary value by combining non-heritage costumes with other regional characteristics and utilizing the local area.

(3) With the advent of the post-epidemic era, virtual reality technology used in the clothing industry can generate applique, flush color samples, a pair of flowers and grids, and rows of materials at zero cost dollars. By reducing the duration of standard production processes, costs can be decreased. Furthermore, the varied display methods and display effects in the fully immersive environment can be effectively utilized in the virtualization instruction of apparel design and the actual operation process of apparel enterprises.

(4) From a clothing psychology perspective, clothing is not only three-dimensional but also overlapping and multidimensional in its interaction with human behavior and the environment. The clothing viewing and consumption environment also have a significant impact on the audience's perception and attention, so the researcher must conduct comparative experiments to determine whether the simplified virtual environment used in this study can direct the subjects' attention more toward the virtual clothing itself or weaken the interaction between the virtual clothing and the environment's expressiveness.

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References

[1] Hong-li Liu; Yu-qing Liang; Xu-hui Li; "The Construction Foundation and Function Design of The Virtual Tourism Teaching System of The Forbidden City", DESTECH TRANSACTIONS ON ENVIRONMENT, ENERGY AND EARTH SCIENCES, 2019.

[2] Qiang Fu; "Virtual Reality Technology in Information Teaching", 2021 2ND INTERNATIONAL CONFERENCE ON COMPUTERS, INFORMATION PROCESSING AND ADVANCED EDUCATION, 2021.

[3] Na Hu; "Research on The Application of VR Technology in Clothing Design Teaching", THE SIXTH INTERNATIONAL CONFERENCE ON INFORMATION MANAGEMENT AND TECHNOLOGY, 2021.

[4] Yuxiu Xue; Jingjing Wang; "English Listening Teaching Device and Method Based on Virtual Reality Technology Under Wireless Sensor Network Environment", JOURNAL OF SENSORS, 2021.

[5] Christian Moro; James Birt; Zane Stromberga; Charlotte Phelps; Justin Clark; Paul Glasziou; Anna Mae Scott; "Virtual and Augmented Reality Enhancements to Medical and Science Student Physiology and Anatomy Test Performance: A Systematic Review and Meta-Analysis", ANATOMICAL SCIENCES EDUCATION, 2021.

[6] Pan, X., & Hamilton, A. F. D. C. “Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape,” British Journal of Psychology, vol. 109, no. 3, pp. 395-417, Mar, 2018.

[7] Gallup, A. C., Vasilyev, D., Anderson, N., & Kingstone, A. “Contagious yawning in virtual reality is affected by actual, but not simulated, social presence,” Scientific reports, vol. 9, no. 1, pp. 294, Jan, 2019.

[8] Dolins, F. L., Klimowicz, C., Kelley, J., & Menzel, C. R. “Using virtual reality to investigate comparative spatial cognitive abilities in chimpanzees and humans,” American journal of primatology, vol. 76, no. 5, May, pp. 496-513, 2014.

[9] Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Scilingo, E. P., & Valenza, G. “Affective computing in virtual reality: emotion recognition from brain and heartbeat dynamics using wearable sensors,” Scientific reports, vol. 8, no. 1, pp. 13657, Jan, 2018.

[10] Z. Hu, C. Zhang, S. Li, G. Wang and D. Manocha, “SGaze: A Data-Driven Eye-Head Coordination Model for Realtime Gaze Prediction,” IEEE Transactions on Visualization and Computer Graphics, (Early Access)1-1, Jan, 2019.

[11] Ivan Stojšić; Anđelija Ivkov-Džigurski; Olja Maričić; "Virtual Reality As A Learning Tool: How and Where to Start with Immersive Teaching", DIDACTICS OF SMART PEDAGOGY, 2018.

[12] Maurício Roberto Veronez; Luiz Gonzaga da Silveira; Fabiane Bordin; Lucas S. Kupssinskü; Gabriel Lanzer Kannenberg; Tiago Duarte; Leonardo Gomes Santana; Jean Luca de Fraga; Demetrius Nunes Alves; Fernando Marson; "RIDERS: Road Inspection & Driver Simulation", 2018 IEEE CONFERENCE ON VIRTUAL REALITY AND 3D USER INTERFACES (VR), 2018.

[13] Óscar González Yebra; Manuel A. Aguilar; Fernando J. Aguilar; Manuel Lucas Matheu; "Evaluation of 3D Immersive Environments in B-learning Implementations", 2018.

[14] Bosede Iyiade Edwards; Kevin Stanley Bielawski; Rui Prada; Adrian David Cheok; "Haptic Virtual Reality and Immersive Learning for Enhanced Organic Chemistry Instruction", VIRTUAL REALITY, 2019.

[15] Paul A Bergl; Rose M Franco; Jayshil J Patel; Marium Khan; Kathlyn E Fletcher; Rahul S Nanchal; "Impact of Fellows-as-Teachers Workshops on Teaching Rounds: An Observational Study in An ICU", CRITICAL CARE EXPLORATIONS, 2020.

[16] Ming Gao; "XR-TECAN Teaching Model for Chinese Traditional Art Education", SCIENCE INSIGHTS EDUCATION FRONTIERS, 2021.

[17] Sebastian Kuhn; Florentine Huettl; Kim Deutsch; Elisa Kirchgässner; Tobias Huber; Werner Kneist; "[Surgical Education in The Digital Age - Virtual Reality, Augmented Reality and Robotics in The Medical School]", ZENTRALBLATT FUR CHIRURGIE, 2021.

[18] Benjy Marks; Jacqueline Thomas; "Adoption of Virtual Reality Technology in Higher Education: An Evaluation of Five Teaching Semesters in A Purpose-designed Laboratory", EDUCATION AND INFORMATION TECHNOLOGIES, 2021.

[19] C H Wu; Y M Tang; Y P Tsang; K Y Chau; "Immersive Learning Design for Technology Education: A Soft Systems Methodology", FRONTIERS IN PSYCHOLOGY, 2021.