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Research Article

The CAD Digital Automation Analysis of Costume Designing Based on Immersive Virtual Reality Models

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With the development of the social economy, costume design is becoming more and more trendy and diversified, which can better reflect cultural and geographical elements. However, traditional costume design often causes excessive waste of resources and time, which is an issue worthy of attention and value. In view of these limitations, an immersive virtual reality model is introduced in this paper. Digitization is realized based on CAD through combing the business logic involved in the costume design process, and virtual fitting and virtual sewing are realized according to virtual reality, and the effect of virtual dressing is viewed and adjusted according to the corresponding feedback, saving cost and time. The simulation experiment research shows that the immersive virtual reality model is effective and can effectively achieve the effective improvement of intrinsic motivation and self-efficacy. Meanwhile, it has a good effect in the assessment of costume design learning transfer and can effectively support the analysis of CAD digital automation.

1. Introduction

With the development of the social economy, people are no longer simply satisfied with traditional material life, and their pursuit of clothing has gradually become diversified [1, 2]. Clothing has changed from traditional Chinese tunic suits and bragis to existing products with cultural and geographical elements, with more diversified connotations [3, 4]. However, the cost of costume design, finished clothing, and clothing fitting is relatively high. Experts in the industry have gradually introduced virtual reality technology, which is a new human-oriented, interactive, and conceptual technology that makes the tasks of costume design more intuitive and improves the efficiency and selectivity of information transmission between related costume designers and customers [5, 6]. In recent years, with the reduction of the cost of VR hardware equipment and the increase of software resource content, the application of VR in costume design has become more and more extensive. Different VR system configurations will bring different levels of immersion and realism. Two types of VR commonly used in costume design are immersive VR and desktop VR [7, 8]. In immersive VR, the user wears a head-mounted display and other related devices to close the external visual and auditory perception, thereby completely perceiving the virtual environment. The interaction with the virtual world is realized by using the supporting locator and handles, such as walking, looking around, grabbing, and dragging. In desktop VR, users usually face the computer monitor and use the keyboard, mouse, or touch screen to interact with the virtual scene [9, 10]. Some scholars have found that the training effects of the immersive VR group and the desktop VR group are better than the map group, and the training effect of immersive VR is better than that of desktop VR under low visibility conditions. The type of VR will significantly affect the participation and presence of students, but there is no significant difference in promoting knowledge acquisition and increasing self-efficacy [11, 12]. However, these studies mainly focus on the evaluation of immediate effects, lacking a comprehensive evaluation of costume design, especially the evaluation of the level of learning transfer [12, 13].

At the moment, people are no longer limited to the simple requirements and needs for the comfort of clothing, but the unique style and temperament shown according to personal needs is more required, and more attention has been paid to fashion and individualization. The costume design industry has gradually been driven by this demand and has gradually formed an informatized and scientific business flow [14, 15]. The use of computers for design and assistance has also become an inevitable trend in costume design.

Costume design is a field closely related to VR. The reason is that VR provides designers with simulation scenarios that can be safely practiced. It is impractical to perform costume design and fitting in the real world at any time, and it is also a waste of time and money [16, 17]. Based on immersive virtual reality, designers have the opportunity to associate corresponding clothing and styles in various environments to exercise their design capacity. For the influence of different virtual realities in costume design, there is still a lack of corresponding scientific and standardized methods for verification. In view of these requirements and limitations, based on the immersive virtual reality model, which elements and comprehensive factors are involved, is explored through combing the process of CAD digitization of costume design, to realize virtual fitting, virtual sewing, and viewing virtual reality based on virtual reality. The effect of dressing is viewed according to relevant feedback, which allows us to timely adjust and revise the corresponding costume design, such as color and style, in order to improve the automation efficiency and digitization of costume design.

2. Immersive Virtual Reality Model

For the so-called digitization of clothing, its essence is to use digital technology to comprehensively integrate computer, Internet, mathematical methods, and other technologies to effectively design, stitch, make, and sell clothing to achieve data collection and aggregation, processing, analysis, and mining for each business flow, to realize the optimization of resource allocation and decision support for apparel companies.

The digital content of costume design mainly includes digital costume design, digital clothing processing, digital clothing sales and management [18–21].

At present, the commonly used measurement methods mainly include contact measurement and noncontact measurement. Noncontact measurement methods mainly include optical-based laser triangulation, laser ranging, structured light, image analysis, and methods based on acoustic waves and magnetism. The measurement of the human body is mostly based on the principle of laser optical triangulation. Three-dimensional human body scanning technology is a measurement technology based on modern optical technology that integrates electronics, computer imaging, information processing, computer vision, software application technology, and sensing technology.

The development of three-dimensional body scanning technology is relatively mature, which can achieve faster measurement speeds and higher measurement accuracy. The image information has also evolved from the original colorless simplified information to capture the color information of each spatial point, which has laid the foundation for the MTM and EMTM of clothing. The Red Collar Group, which focuses on clothing customization, has launched a clothing 3D body measuring instrument to provide customers with fast and accurate body measurement services. The red-collar measuring body needs to measure 22 data in 19 parts. These data become the source of driving the operation of the entire system. The change of each data will lead to the linkage of 9996 data of one version, which realizes "one person, one version, one version." One piece of clothing, one piece of first-class; Aimer underwear also provides digital measurement services to meet the requirements of customers, so that the underwear can better meet the needs of customers; Dalian Polytechnic University has measured a large amount of human body data information through three-dimensional scanning technology. A human body database for young women is established in the Northeast region, combined with the database to study the standard body size of young women in the Northeast region and combined the aesthetic principles to shape the human body model by hand, and then scanned and digitally corrected it and finally used 3D printing technology to output an environmentally friendly human body model. This method is embedded with the concept of reverse engineering and is also an important application of 3D scanning technology.

3. Application of Garment CAD Technology

For human body scanning technology, there are currently two main types: contact type and noncontact type. Noncontact type mainly uses laser scanning, structured light method, image analysis, acoustic wave analysis, and so on. The development of three-dimensional body scanning technology is relatively mature, which can achieve faster measurement speeds and higher measurement accuracy.

The essence of the costume design CAD system is the use of computers to assist costume design, that is, the computerization and informationization of clothing product design, and the CAD technology is used to realize two-dimensional piece analysis of costume design. With the continuous development of three-dimensional technology, the transformation of two-dimensional pieces into three-dimensional pieces has become the focus and direction of research.

4. The Principle and Application of Virtual Stitching and Fitting Technology

Three-dimensional clothing modeling is a virtual simulation study for costume design, to achieve the virtual simulation of clothing modeling design. Costume design, clothing sewing, and fitting can be used to realize the virtual simulation, virtual sewing, clothing deformation constraint control, and collision detection of two-dimensional cutting pieces. Supported by the computer, mature and formed styles, color matching, layout distribution, etc. can be shared. Meanwhile, two-dimensional cutting pieces are used for virtual stitching to realize human body collision detection and realize the conversion of two-dimensional cutting pieces to three-dimensional pieces.

At present, the most widely used virtual stitching software in China is as follows: the CLO 3D virtual stitching software is a garment virtual stitching software developed and developed by Shanghai Jiana Textile Technology Co., Ltd., Korea Crow Company, and French Ooster Company. It realizes a smart clothing design system integrating human body scanning, virtual stitching, and virtual display of models. The German Assyst system is divided into different modules, which can achieve precise drawing of 2-D pieces and 2-D cutting. The virtual stitching of pieces, the virtual try-on of 3-D garments, and the MTM tailor-made system combined with anthropometric measurements realize the seamless connection between the three-dimensional scanning table and the three-dimensional fitting.

AR technology is a technology that superimposes virtual objects on real objects through 3D technology to achieve a hybrid and enhanced viewing angle. On the basis of VR technology, AR technology organically integrates the real world and digital virtual information and uses the design functions of computer-related software to apply virtual technology to the real world. AR technology superimposes digital virtual information and the real world into the same perspective space, allowing learners to recognize virtual images and information in the real world, so as to achieve better augmented reality effects through interaction with the surrounding environment. The higher the degree of overlap between the real world and digital virtual information, the stronger the role of learners to participate in the interaction, and the better the augmented reality effect of the learning environment. AR technology generally uses holographic glasses and other devices to perceive information and the environment and enhance the realism and mutuality of learning.

Here, we need to make a unified distinction between AR technology, VR technology, and MR technology. Since AR technology is based on VR technology, the real world and the digital world are more integrated. Using computer technology to embed the real world, that is, computer technology is used to superimpose the real world into the same perspective so that a third party can see both virtual objects and the real world. This combination of virtual and real can better show the advantages of AR technology and enhance the reality effect.

MR technology is to conduct the visualization simulation based on the corresponding virtual reality technology and AR technology through the integrated real environment. In essence, VR technology is based on the virtual environment, AR technology is a combination of virtual and real, and MR technology is a further step in superposition modification to further enhance the interactivity.

The difference and connection of the three technologies of VR, AR, and MR are shown in Figure 1. It can be seen that, in terms of function, MR > AR + VR, that is, MR technology is the integration and upgrade of AR, VR technology and its equipment.

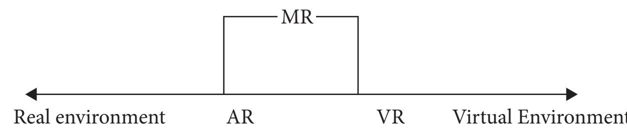

Figure 1: Differences and connections among the three technologies of VR, AR, and MR.

5. Six-in-One Digital Process System

Digital technology runs through every process from costume design to production, and truly realizes the six-in-one digital process system of measuring, drawing, sewing, fitting, modifying, and making. The measurement refers to the three-dimensional body measurement technology , drawing refers to the CAD computer-aided design technology of the clothing CAD, sewing refers to three-dimensional virtual stitching technology, fitting refers to three-dimensional fitting technology, modification refers to the modification of sample garments based on digital means, and making refers to garment CAM computer-aided manufacturing technology. The digital process system is shown in Figure 2. After digital measurement and tailoring and virtual stitching, the clothing can be intuitively observed to see its effect on the human body. Meanwhile, if there are inappropriate places, they can be modified, which greatly improves the fitness of the clothing and the user's degree of satisfaction.

6. Research Design

6.1. Research Object. In this study, a total of 122 freshman students (including 47 boys and 75 girls) from 3 majors of pedagogy, preschool education, and educational technology from a certain university were selected as the research objects. These students need to participate in costume design training. Participants were randomly divided into two groups for costume design training according to the stratification. Among them, immersive VR was the experimental group with 61 people in total, and desktop VR was the control group with 61 people in total. The specific grouping situation is shown in Figure 3.

6.2. Experimental Design. The experimental design of this research draws on the VR experimental research framework of existing scholars. On the day before the training, the researcher explained the training process and assessment methods to the students, and told the students that only after the knowledge test was passed with 80% accuracy and with successful completion of the practical operation in the real costume design situation can they finally obtain the costume design access security certificate. Then, the researcher asked the students to fill in a questionnaire about the education of fashion design, which mainly included prior knowledge, intrinsic motivation, and self-efficacy. On the day of the training, the two groups of students entered the costume design site according to the list. The researcher again emphasized the training process to the students. After

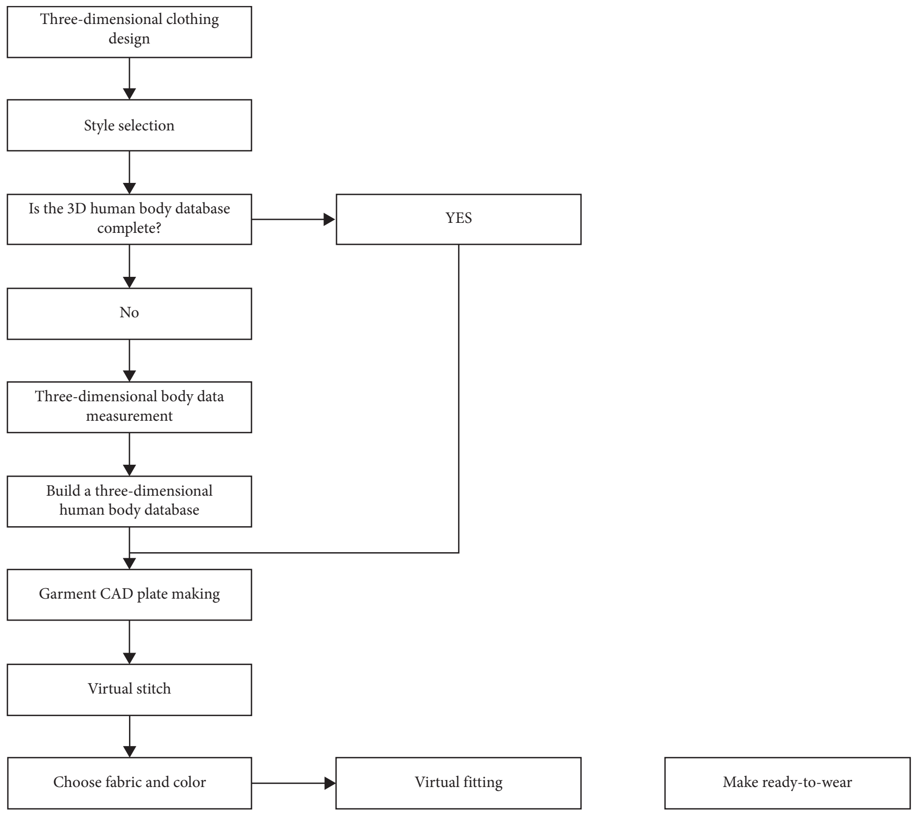

Figure 2: The six-in-one digital process system of measuring, drawing, sewing, fitting, modifying, and making.

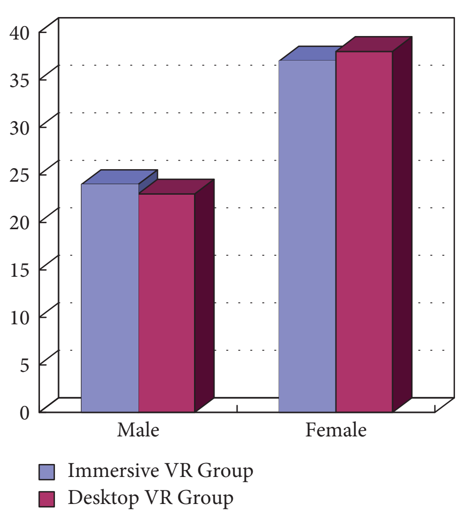

Figure 3: Experimental grouping situation.

confirming that the students had no doubts, the two groups of students carried out immersive virtual simulation learning of costume design with the same content. The difference is that students in the immersive VR group use HTCVIVE handles and head-mounted displays for training, while students in the desktop VR group use keyboard, mouse, and computer monitors for training. The training time of the two groups is 40 minutes, and the training is organized by the same teacher. At each training place, there is an experimental assistant who is responsible for issuing test papers and keeping order. After the training, all students immediately filled in the costume design training questionnaire and then answered the posttest knowledge test paper. One week after the training, the researcher arranged for all students to conduct a learning transfer assessment of practical operation of costume design. The learning transfer assessment is divided into two parts: the first part is to ask students to evaluate the influencing factors of real costume design; the second part is to ask students to modify the clothing according to questions raised by customers in the costume design. After the above link is over, the researcher analyzes the experimental results.

6.3. Experiment Content. In this study, guided by target taxonomy, 3D game engine design was used to develop immersive and desktop VR teaching resources for costume design training. Students will perform costume design tasks in a VR environment, mainly receiving information related to the learning task through voice prompts, such as task type, content, answers, and feedback. The system also provides texts and illustrations to help students consolidate their knowledge and strengthen exercises. In the VR system, students understand the operation guide for costume design, that is, how to use the equipment to interact with the VR environment. Throughout the practice process, the system will ask learners about safety issues and give interpretive feedback to promote learning reflection.

6.4. Measuring Tools. The evaluation tools used in this study include a participant questionnaire before and after training (response level), a safety knowledge retention test (learning level), and two learning transfer test questions (behavior level) in a real costume design environment.

In the response layer of the evaluation model, the pretraining participant questionnaire includes measurements of prior knowledge, intrinsic motivation, and self-efficacy. The prior knowledge measurement contains 7 items, which are used to evaluate the students' mastery of prior knowledge and experience in costume design. Of which, the first question asks participants to evaluate their level of costume design knowledge. The other 6 questions are divided into two parts, and the 3 questions are used to ask students to choose the events they have experienced, such as "I have received training in fashion design before." The other 3 questions are used to ask students to choose answers.

At the learning level of the assessment model, the knowledge retention test is developed by the instructor and reviewed by 3 fashion design experts. It contains 18 single-choice questions with a total of 18 points, which is closely related to the knowledge of laboratory safety facts, concepts, and procedures, aiming to test students' memory and understanding of training content. At the behavioral level of the evaluation model, the posttest learning transfer assessment was developed by the instructor and reviewed by 3 fashion design experts. The first costume design assessment test focuses on testing students' costume design adaptability. In this test link, students have 8 minutes to observe the real scene and write as many violations as possible on the answer sheet. This process requires students to complete this process independently and does not carry out mutual communication. Students receive 1 point for each correct identification of safety violations, and the total score is between 0 and 8. In this test link, two students form a group, and all members of the group receive training under the same conditions.

The three-dimensional integrated system is divided into three parts: the three-dimensional body scanner system, the fitting system, and the database retrieval system (Figure 4).

Virtual fittings are used for improvement of the speed and efficiency of model garment making, and meanwhile, the related costs of making clothes can be reduced. At the same time, virtual fitting is used to, on the one hand, improve the user experience; meanwhile, it can be used to make a three-dimensional model of the human body to match each other with virtual clothes to achieve online virtual fitting; on the other hand, it can integrate relevant elements of clothing, namely, styles, and reduce the time associated with making clothes.

In the rectangular block model of the pattern design, the Jacobi iteration iterative algorithm is used to perform the brightness equalization and restoration of the image, and the conductivity equation of the best matching block area can be used, as shown in formula (1):

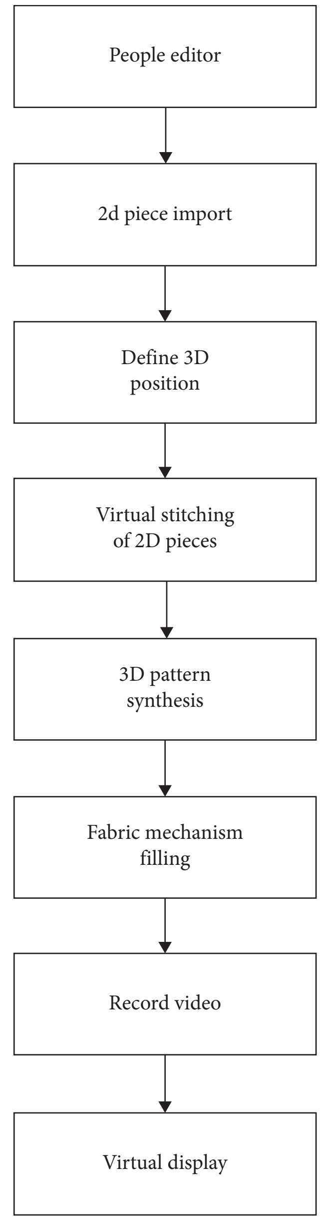

Figure 4: Operation flow chart of sewing and displaying virtual samples.

$$h(x, y) = \frac{\lambda}{2\pi\sigma^2} \exp\left[-\frac{1}{2}\left(\frac{x'^2 y'^2}{\sigma^2} + \frac{\lambda^2 y'^2}{\sigma^2}\right)\right] \cdot \text{exo}\left[2\pi jFx'\right]. \tag{1}$$

Meanwhile, calculate the distribution sequence of the new edge pixels, as shown in formula (2):

$$\phi_n = \frac{\pi k}{N}, \quad k = 0, 1, 2, \cdots, N - 1. \tag{2}$$

The specific adjustment of the priority coefficient of the block to be repaired is shown in formula (3):

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(-\theta_1) & -\sin(-\theta_1) & 0 \\ \sin(-\theta_1) & \cos(-\theta_1) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}. \tag{3}$$

In the folding area, the surface of the fabric will form convex or concave folds along with the unevenness of the folding line (Figure 5).

Figure 6 shows a pleated fabric pattern with transversely folded regions.

Figure 7 is a schematic diagram of fabric warp fold formation.

According to the statistical analysis of the study, the reliability coefficients of all scales used are calculated using coefficients. The results show that the pretest and posttest reliability of the Intrinsic Motivation Scale are 0.86 and 0.81, respectively, the pretest and posttest reliability of the self-efficacy scale are 0.90 and 0.88, respectively, and the reliability value of the perceived Pleasure Scale is 0.93. Before conducting safety training, it is investigated in this study whether there was a difference in prior knowledge between the two training groups. The independent sample T test showed that $p = 0.17 > 0.05$, so there was no significant difference in prior knowledge between the two groups.

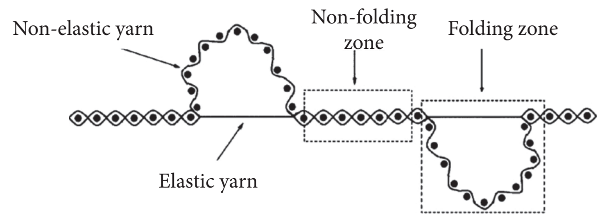

Figure 5: Schematic diagram of fabric latitudinally-trending fold formation.

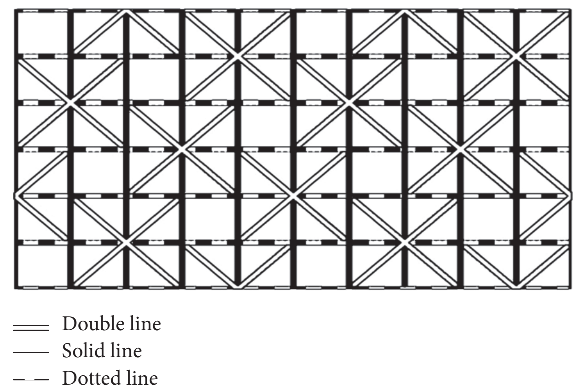

Figure 6: Pleated fabric pattern with transverse folding area.

6.5. The Impact of Different Types of VR Learning Environments on Learning Attitudes

(1) Perceived joviality

The average perceived joviality rating of the two groups of students is very high, and the immersive VR group is slightly higher than the desktop VR group. This shows that there is no significant difference between immersive VR and desktop VR in promoting students' enjoyable learning experiences. Both groups of students have a high degree of recognition for their VR learning environment.

(2) Intrinsic motivation

In order to understand whether learners' intrinsic motivation will differ due to different types of VR, the pretest intrinsic motivation scores of the two groups of students are used as covariates, and the posttest intrinsic motivation scores are used as dependent variables. There was a significant difference in the posttest intrinsic motivation score between the two groups, $F = 4.4$, $p = 0.03 < 0.05$. It shows that compared with a desktop VR environment, the use of an immersive VR environment in the training process can significantly increase the intrinsic motivation of students.

(3) Self-efficacy

First, the independent variables and covariates are tested for the homogeneity of the slopes. The result is $0 = 0.169 > 0.05$, indicating that the interaction between learning style and pretest self-efficacy scores is not significant. It satisfies the hypothesis of slope homogeneity and is suitable for covariance analysis.

The results of the analysis of covariance are shown in Figure 8. The adjusted average and standard errors of the desktop VR group are 6.122 and 0.048, respectively, and the adjusted average and standard errors of the immersive VR group are 6.283 and 0.049, respectively. There were significant differences in posttest self-efficacy scores between the two groups, $F = 5.440$, $p = 0.021 < 0.05$. This shows that compared with the desktop VR environment, the self-efficacy of the students in the immersive VR group after training is significantly improved.

6.6. The Impact of Different Types of VR Learning Environments on Knowledge Acquisition. In order to test whether the knowledge of learners after training will be different due to different VR categories, the data shows that the average value of the desktop VR group is slightly higher than that of the immersive VR group ($p = 0.82 > 0.05$), and there is no significant difference between the knowledge retention test scores between the two groups of students. This shows that immersive VR and desktop VR are equally effective in helping students master the basic knowledge of the presented materials.

6.7. The Impact of Different Types of VR Learning Environments on Learning Transfer. In order to further test whether the different types of VR will affect learners to use CAD digital automated analysis to solve problems in real situations, independent sample T tests are conducted on the two assessment results of learning transfer, and the results are shown in Figure 9 in this study. The data show that the costume design evaluation score ($p = 0.02 < 0.05$) between

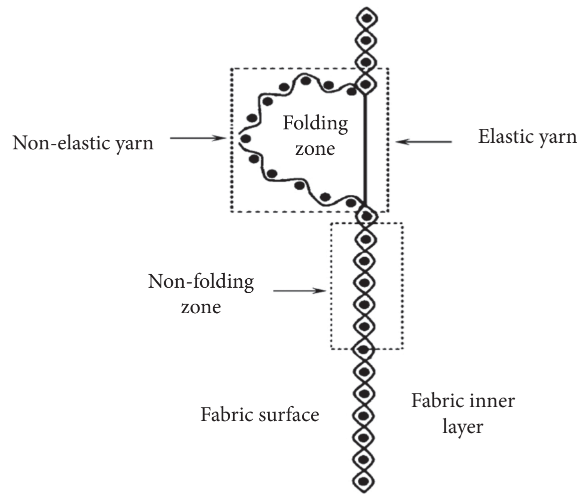

Figure 7: Schematic diagram of fabric warp fold formation.

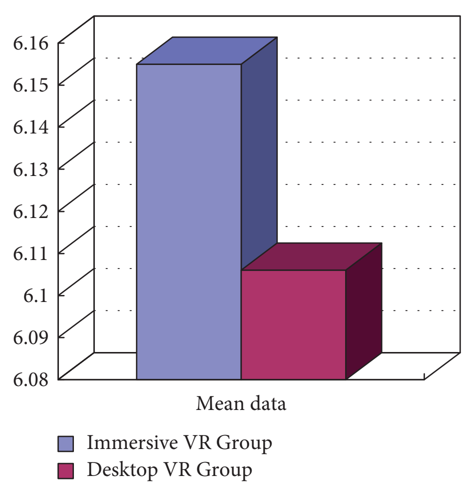

Figure 8: Descriptive statistics of posttest intrinsic motivation.

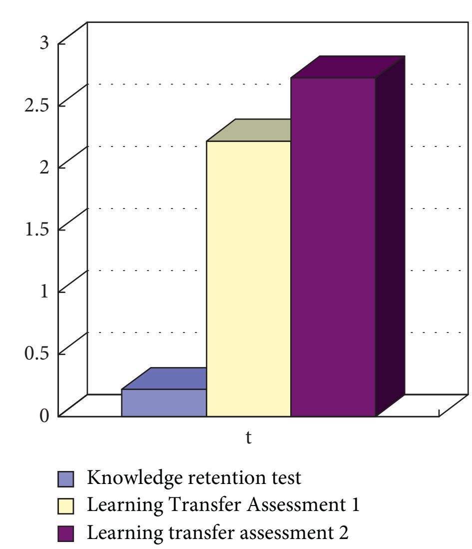

Figure 9: Independent sample T test results of knowledge retention test and learning transfer assessment results.

the two groups, and the feedback emergency modification clothing evaluation score ($p = 0.01 < 0.05$), that is, there is a significant difference in the learning transfer evaluation scores between the two groups of students, relying on immersive VR. The students who studied in the environment performed better than those in the desktop VR group in the two learning transfer assessments. The simulation experiment proved the effectiveness of the immersive virtual reality model.

7. Conclusions

The development of the social economy has promoted the diversified development of clothing, but how to effectively design and realize CAD digital automation analysis has become a problem for humans. The immersive virtual reality model is introduced in this paper. Computer CAD is introduced for digital automation analysis, which realizes virtual fitting, virtual sewing, virtual clothing making, and viewing the effect of virtual clothing through the analysis of the related business flow of costume design. Modification is performed according to the customer's levant opinions in time to reduce costs and time. The simulation experiment research shows that the immersive virtual reality model is effective.

Data Availability

The labeled dataset used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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