A Study on the Application Innovation of Virtual Simulation Technology in Clothing Structure Teaching and its Effect on Improving Students' Practical Abilities

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ABSTRACT The teaching of garment structure suffers from deficiencies in spatial cognition and practical proficiency, limiting students' ability to transform two-dimensional patterns into three-dimensional garments and reducing teaching efficiency. As virtual interaction and intelligent sensing technologies become increasingly important in digital engineering environments, integrating immersive simulation with multidimensional information processing provides new opportunities for educational innovation. This study introduces Virtual Simulation Technology (VST) to construct a teaching system based on three-dimensional garment construction and virtual operation. The proposed framework establishes a multi-dimensional garment pattern database to support teacher–student interactive design, employs simulation software for three-dimensional cutting and dynamic fitting to enhance intuitive understanding of structural changes, and conducts comparative teaching experiments between virtual simulation and conventional instruction. Experimental results demonstrate that students using the VST-based approach achieve a 22.4% improvement in garment structure reading and pattern design assessments, while course participation satisfaction reaches 92.3%. The findings indicate that virtual simulation effectively strengthens spatial perception and practical skills, providing a feasible reference for intelligent digital education and interactive visualization systems.

INDEX TERMS virtual simulation technology, clothing structure teaching, practical skills, intelligent visualization, digital interaction

I. INTRODUCTION

A. RESEARCH BACKGROUND

THE fashion design major must cultivate students' comprehensive abilities by integrating clothing structure teaching with a deep technical understanding of textile material properties and fabric performance. This synergy ensures that students can effectively translate structural concepts into high-quality textile products that meet the rigorous functional and aesthetic standards of the modern garment industry. It requires solid theoretical knowledge and also emphasizes the integration of spatial conception, pattern design and practical operation [1,2].

Currently, the demand for highly qualified design and craftsmanship talents in the apparel industry continues to grow. Students need to understand structural principles and, more importantly, possess the ability to construct, adjust, and display clothing in a digital environment.

In teaching, how to help students transition from two-dimensional cognition to three-dimensional perception has become the key to improving learning effectiveness.

Currently, the teaching process still suffers from a situation where teachers primarily lecture and students passively receive information. The lack of visual and interactive support in the classroom results in students having a superficial understanding of three-dimensional structures.

In practice, the consumption of physical materials is large and the sample preparation cycle is long, making it difficult to support repeated experiments and creative thinking training [3,4]. These problems combined restrict the improvement of teaching efficiency and students' innovative ability, prompting the education model to be reformed with the help of new technologies.

B. PROBLEM ANALYSIS

The course on clothing structure involves the transformation from two-dimensional paper patterns to threedimensional garments, which requires a high level of spatial cognition and structural perception.

However, most students have difficulty understanding the relationship between pattern changes and structural connections, and lack the ability to transform theoretical knowledge into practical operation [5,6]. Traditional teaching relies on two-dimensional diagrams and verbal explanations, which makes it difficult to achieve real-time visual verification. As a result, students have low sensitivity to design errors and insufficient grasp of the internal logic of clothing styling.

Limited resources are allocated to practical teaching, and the high cost and consumption of sample garment production limit the frequency of hands-on activities. The low reuse rate of teaching resources and the disconnect between teaching content and industry technology are becoming increasingly prominent issues.

The lack of teaching experience based on digital simulation platforms among some teachers has inadvertently weakened the interactivity and innovative atmosphere of the courses. These bottlenecks have become key factors restricting the development of students' abilities [7,8].

C. RESEARCH OBJECTIVES AND SIGNIFICANCE

This paper proposes to develop a three-dimensional teaching platform for clothing structure by introducing Virtual Simulation Technology (VST), thereby realizing the visualization, interactivity and intelligent management of the teaching process.

Through the VST system, students construct 3D pattern databases and dynamic fitting models that incorporate precise textile material parameters to simulate real-world fabric behavior during virtual cutting, splicing, and shaping. This digital integration allows for an intuitive mastery of structural transformation laws by visualizing how different textile weaves and weights react to complex garment geometries in a simulated environment.

The significance of this study is mainly reflected in three aspects:

(1) Promote the transformation of clothing structure teaching methods from experience-based to datadriven;

(2) Provide students with a low-cost, high-efficiency virtual experimental environment to improve their hands-on skills;

(3) Strengthen teachers' awareness of integrating teaching resources and innovative teaching design.

By integrating technology with teaching, we can cultivate students' structural perception, problem-solving thinking, and innovative awareness, providing a practical basis for the digital reform of clothing education.

D. PROGRESS AND SHORTCOMINGS IN TEACHING CLOTHING STRUCTURE

Internationally, virtual simulation technology is applied to engineering education, medical training and industrial design fields. Some art and design colleges have also introduced 3D modeling and simulation fitting systems, such as CLO 3D and Browzwear, into their clothing teaching to achieve an integrated teaching model from pattern design to dynamic display. The application of this technology can enhance students' modeling perception and spatial control ability [9,10].

In China, some scholars have made initial attempts in pattern reading and garment technology courses, but systematic research is insufficient, and the application of technology is basically limited to the demonstration level, making it difficult to deeply integrate with teaching objectives.

While some universities have achieved good results in their teaching experiments, they lack unified standards and data verification support.

Therefore, it is evident that constructing a virtual simulation system based on teaching needs and conducting quantitative analysis of its teaching effectiveness from a practical perspective has significant theoretical value and promotional significance [11].

II. DESIGN AND CONSTRUCTION OF VIRTUAL SIMULATION TECHNOLOGY IN CLOTHING STRUCTURE TEACHING

A. VST SYSTEM FUNCTIONAL ARCHITECTURE

The system function design of VST in clothing structure teaching follows three principles: "visual, operable, and evaluable". This paper needs to be guided by teaching needs and build a multi-dimensional teaching platform that integrates modeling, simulation and interaction.

The overall system architecture is divided into four core modules: data management layer, model generation layer, simulation interaction layer, and teaching evaluation layer.

(1) In the data management layer, the system establishes a multi-dimensional clothing pattern database, covering different clothing structural parameters, fabric properties and sewing logic, to provide standardized data support for students' design experiments.

(2) The model generation layer uses 3D modeling technology to match the mechanical parameters and shape features of the fabric, and can respond to and render structural changes in real time.

(3) The simulation interaction layer supports students to perform three-dimensional cutting, stitching construction and pattern adjustment in virtual space. The operation results are presented in real time, which strengthens the synchronous learning of structural cognition and spatial perception.

(4) The teaching evaluation layer integrates teacher evaluation with system quantitative analysis to visualize the student learning process and make the results traceable, providing data basis for teaching assessment.

This system architecture enables multi-dimensional linkage and intelligent support in the teaching process.

B. VIRTUAL OPERATION AND TEACHING MODULE DESIGN

The core of the teaching module design is to realize an integrated learning process of "concept-operationverification" through simulation technology, so as to promote the transformation of students' abilities from cognition to practice.

The system is divided into three main teaching modules: structural cognition module, three-dimensional cutting module, and dynamic simulation module.

(1) The structural cognition module presents the principles of clothing structure through a three-dimensional visualization interface. Combined with the layered analysis function, it enables students to observe the splicing logic and shape changes of various parts of clothing.

(2) The 3D pattern-making module allows students to set various fabric properties and sewing parameters through a virtual control panel. Students can select different patterns to virtually overlap and unfold them, comparing the transformation process from flat to three-dimensional.

(3) The dynamic simulation module uses physical simulation algorithms as its core to simulate physical properties such as gravity and elasticity, enabling virtual clothing to undergo shape changes and comfort analysis in dynamic environments.

The teaching module is also equipped with operation recording and instant feedback functions. Every parameter adjustment and splicing operation by the student will be automatically recorded by the system and a personalized learning report will be generated.

Teachers can monitor students' learning progress and operational paths through the backend system, providing targeted guidance for problematic areas and improving the relevance and effectiveness of teaching.

C. TEACHING PLATFORM INTEGRATION AND OPERATION MECHANISM

The design of the integration and operation mechanism of the teaching platform focuses on flexibility, compatibility and scalability. The system adopts a cloud data interaction architecture to realize synchronous operation of multiple terminals and sharing of teaching resources.

The teaching platform is divided into two parts: the teacher's side and the student's side. The teacher's side is responsible for course content management and resource publishing, while the student's side is used for simulation operations and self-study.

The two ends are connected in real time through a cloud database to ensure data consistency and smooth interaction during the teaching process.

The platform operation process includes four stages:

(1) Teachers set teaching objectives and task templates, and the platform automatically generates corresponding practice modules;

(2) Students log into the system and complete structural design and operation tasks in a virtual space;

(3) The system provides real-time simulation feedback based on students' operational behavior and generates learning data logs;

(4) Teachers can review the results through a visual analysis interface, and the system automatically calculates the accuracy and completion rates of the operations, thus achieving intelligent evaluation.

In terms of operation mechanism, the platform adopts a modular expansion strategy, which can flexibly embed different course content or clothing category learning units. By connecting with the learning management department of universities, it can realize the tracking of teaching process data, progress monitoring and result archiving. The entire system has good operational stability and teaching sustainability.

III. DESIGN AND IMPLEMENTATION PROCESS OF TEACHING EXPERIMENTS

A. EXPERIMENTAL OBJECTIVES AND HYPOTHESES

The purpose of the experiment was to better examine the practical application effect of VST in clothing structure teaching, mainly focusing on changes in students' understanding of structure, operational accuracy and learning initiative.

This study uses a comparative experiment to evaluate the effectiveness of the VST teaching model in promoting students' spatial thinking, creativity, and learning engagement. The experiment sets the following three core objectives:

(1) To verify whether VST technology can improve students' understanding of pattern recognition and three-dimensional modeling;

(2) To analyze whether virtual simulation operations can improve students' practical skills and design accuracy;

(3) To examine learners' learning interest and willingness to explore independently in an interactive environment.

Based on this, the following research hypotheses are proposed:

Hypothesis H1: Students in the VST teaching group will have a significantly higher level of theoretical mastery than those in the control group.

Hypothesis H2: Using VST teaching can effectively improve students' accuracy in practical clothing structure operation.

Hypothesis H3: The VST teaching model helps to enhance students' learning initiative and classroom participation.

The basis for quantitative data verification is the setting of experimental hypotheses, which ensures that the research results are statistically significant. The feasibility of the virtual simulation teaching model is verified by analyzing the scores, operation data and questionnaire feedback.

B. EXPERIMENTAL SUBJECTS AND GROUPING

The experiment selected 60 second-year students majoring in fashion design, all of whom had completed the basic pattern-making course and possessed basic skills in fashion graphic design. This study was approved by the Ethics Committee of Luohe Vocational Technology College, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

Students were randomly assigned to experimental and control groups using a balanced grouping method, with 30 students in each group. After pre-examination, no significant difference was found in the basic academic level of the classes ($p>0.05$).

(1) Experimental group: The VST teaching model was adopted, in which a virtual simulation platform was used to design clothing structure, simulate cutting and verify dynamic fit during the teaching process, and the system recorded the learning process and operation data.

(2) Control group: Continued to use conventional classroom teaching methods, with physical paper patterns and sample garment making as the main practice means, and the content was taught according to the same teaching objectives.

This experiment was designed to last for eight weeks, totaling 32 class hours, and included four teaching stages: "structural analysis, pattern making, cutting practice, and garment verification." The entire course was taught by the same instructor, and the content of the two groups of courses was identical, with the only difference being the teaching media and technical methods.

During the experiment, students' learning outcomes, operational behaviors, and classroom feedback were recorded simultaneously to ensure the objectivity and comparability of the data.

C. EXPERIMENTAL PROCEDURE

The entire experiment was divided into four main stages, following the logical path of "pre-test - teaching - post-test - assessment".

(1) Pre-test phase: Before the experiment begins, two groups of students are assessed on their basic abilities, including three indicators: pattern recognition, spatial reasoning, and operational accuracy, to establish a baseline level.

(2) Teaching phase: The experimental group was required to complete the three-dimensional virtual structure design, fabric property selection and dynamic fitting operation through the VST platform, while the control group completed the production of physical sample garments according to the same teaching objectives. The learning time, error rate and number of revisions were recorded synchronously throughout the teaching process.

(3) Post-test phase: After 8 weeks of teaching, a unified assessment will be organized, which will cover theoretical tests and practical tasks. Data from various indicators will be extracted from the system, and a learning experience questionnaire will be conducted for students.

(4) Evaluation phase: SPSS software was used to perform independent samples t-tests and analysis of variance on the two groups of data, calculate the mean difference and significance level, and conduct a comprehensive evaluation in conjunction with the questionnaire results.

By comparing and analyzing the differences among students in terms of grades, operational accuracy, and learning attitude, we can determine the effectiveness and scalability of virtual simulation technology in teaching clothing structure.

TABLE 1. Comparative Analysis of Teaching Effectiveness

Indicator Categories	control group average	average value of experimental group	Increase (%)	Significance level (p)
Mastering theoretical knowledge	78.4	95.8	22.2	0.032
Structural reading ability	74.5	91.3	22.6	0.028
Pattern design accuracy	72	88.5	22.9	0.025
Overall score (general average)	75	91.8	22.4	0.027
Number of errors corrected (per person)	6.1	3.4	↓44.3	0.041

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. COMPARISON OF TEACHING EFFECTIVENESS

In this section, we need to statistically analyze and compare the academic performance of the experimental group and the control group after the course ends. The data here covers four dimensions: theoretical scores, structural reading ability, pattern design accuracy, and overall scores.

The comparison results need to be analyzed using SPSS software with an independent samples t-test, and the significance level is set at 0.05. Table 1 shows the comparative analysis of teaching effectiveness:

The data in Table 1 clearly shows that the experimental group students demonstrated significant advantages in both theoretical understanding and pattern design accuracy. Their overall scores were 22.4% higher than those of the control group, a statistically significant difference ($p<0.05$).

Because the virtual environment can provide real-time feedback on errors and allows for multiple experiments, students reduced the number of modifications they needed when revising the structure by 44.3%. This demonstrates that the VST platform effectively improved the trial-and-error mechanism in the learning process, enhanced cognitive depth and operational accuracy through real-time simulation demonstrations, and promoted the integration of theory and practice.

B. LEARNING EXPERIENCE AND PARTICIPATION

After the above experiment, a questionnaire survey was conducted among the participating students. The survey consisted of five dimensions: learning interest, classroom participation, willingness to learn independently, collaborative communication, and overall satisfaction. A total of 60 questionnaires were distributed and all were returned. Table 2 shows the statistical results of students' learning experience and classroom participation:

Analysis of the data in the table above shows that the experimental group students were significantly higher than the control group in all indicators, and the overall satisfaction rate was 92.3%.

TABLE 2. Statistical Results

Evaluation Project	Control group mean (out of 5 points)	Mean score of the experimental group (out of 5)	Difference range (%)	Satisfaction rate (%)
Enhance learning interest	3.2	4.6	43.8	91.7
Classroom interaction frequency	3.1	4.4	41.9	93.1
Willingness to learn independently	3.3	4.7	42.4	94.5
Teamwork and Communication	3.4	4.5	32.4	90.8
Overall learning satisfaction	3.5	4.8	37.1	92.3

TABLE 3. Comparison of Teaching Resources and Efficiency Improvement

Evaluation Project	Control group data	Experimental group data	Improvement rate (%)	illustrate
Effective teaching time per lesson (minutes)	35.6	47.2	32.6	Simulation operation reduces preparation time
Material consumption cost (RMB/person)	62.4	31.8	↓49.0	Virtual samples replace physical samples
Teaching resource utilization rate (%)	68.7	93.4	36	The platform enables resource sharing.
Teachers' time spent on lesson preparation and grading (hours/week)	7.5	4.6	↓38.7	The system automatically generates learning reports.
Overall Teaching Efficiency Index (Comprehensive)	1	1.42	42	Data-driven teaching improves efficiency

Most students felt that the VST platform made the learning process more immersive and interactive, and enhanced their understanding of clothing design principles through virtual try-on and dynamic structural feedback.

Students can freely select structural parameters in the system and immediately observe the molding effect, effectively enhancing their learning autonomy.

The interview results show that about 83% of students believe that virtual simulation teaching is more effective in stimulating creative thinking than traditional teaching. The increased frequency of teaching interaction also promotes the optimization of the learning atmosphere. This indicates that the teaching model has achieved significant results in terms of student experience and behavioral participation.

C. IMPROVEMENT OF TEACHING RESOURCES AND EFFICIENCY

Table 3 compares the improvements in teaching resources and efficiency:

The effective teaching time per class period in the experimental group increased by 32.6% compared to the control group, the utilization rate of teaching resources increased by 36%, and the material cost was almost halved. The automated recording and data tracking functions reduced the time teachers spent on teaching preparation and grading, resulting in an overall efficiency improvement of 42%.

The data above demonstrates that virtual simulation systems not only improve the economy and flexibility of the teaching process, but also enable the efficient recycling and sharing of resources.

From an overall perspective, the introduction of VST has enabled the teaching of clothing structure to shift from "experience-driven" to "data-driven," making the teaching chain more complete and the process more transparent. Resource conservation and efficiency improvement complement each other, providing a verifiable path and practical basis for educational informatization and sustainable teaching reform.

V. CONCLUSION AND OUTLOOK

This paper constructs a clothing structure teaching system based on VST that integrates digital textile performance data, demonstrating through experiments its significant advantages in enhancing teaching quality and students' mastery of complex fabric-to-pattern interactions. By synchronizing virtual simulation with real-world textile characteristics, the model achieves superior learning outcomes in technical precision and material application. The VST teaching model can effectively improve students' structural reading ability, spatial thinking depth, and operational accuracy.

The VST teaching model realizes the digitization, interactivity, and intelligence of the teaching process, providing a feasible path for the modernization of clothing structure courses and offering new ideas for professional teaching reform in colleges and universities under the guidance of "student-centeredness".

Future research can further improve the functionality of the VST system by adding intelligent assessment and AI-assisted design modules, enhancing the personalization and adaptability of teaching. Virtual simulation technology will play a broader supporting role in the apparel education system by integrating digital textile material testing and fabric behavior modeling to promote the transformation of teaching from "knowledge transmission" to "competency building." This technological synergy ensures the cultivation of apparel professionals possesses the technical agility to synchronize complex garment construction with evolving textile manufacturing standards, injecting lasting innovative momentum into the industry.

AUTHOR CONTRIBUTIONS

Jing Shi designed, collected and analyzed the data, and drafted the manuscript. Jing Shi conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Jing Shi participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of Luohe Vocational Technology College, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

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