

## Research on Enhancing Artistic Expression through the Interactive Design of Paintings and Smart Textiles

Chen Liu

**How to cite:** Liu C. Research on Enhancing Artistic Expression through the Interactive Design of Paintings and Smart Textiles. Textile & Leather Review. 2026; 9:3659-3679. <https://doi.org/10.31881/TLR.2026.3659>

**How to link** <https://doi.org/10.31881/TLR.2026.3659>

**Published:**25 April 2026



# Research on Enhancing Artistic Expression through the Interactive Design of Paintings and Smart Textiles

**Chen Liu**

Academy of Arts, Shanghai Zhongqiao Vocational and Technical University, Shanghai 201514, China  
chenliushzq@126.com

## Article

<https://doi.org/10.31881/TLR.2026.3659>

Published 25 April 2026

---

### ABSTRACT

*This study explores the innovative path of integrating intelligent textiles and painting art and breaks through the boundary of traditional design. It focuses on the application of painting art in intelligent textiles and examines it from the perspectives of artistic expression, interaction, durability, functionality, user satisfaction, innovation, and market potential. The differences and causes of each index between the experimental group and the control group are deeply analyzed through the comparison of experimental data. In terms of artistic expression, given the complex constraints of the integration of technology and art, the experimental group scored higher than the control group in the color matching score, pattern creativity score, style uniqueness score, and total artistic expression score. Interactivity, durability, and other indicators are also affected by materials, technology, and design, thus showing different performances. The research reveals that the design combining painting art with smart textiles has outstanding potential in innovation. However, it faces challenges in technology realization, cost control, and user experience balance. This study provides a key reference for the design optimization, performance improvement, and market promotion of intelligent textile fusion painting art.*

### KEYWORDS

*painting art, intelligent textiles, interactive design, artistic expressive force*

---

### INTRODUCTION

In today's era, the integration of technology and art has become an important force to promote innovation and development in various fields. As a new product under this integration trend, smart textiles have shown vigorous development vitality and potential in the field of modern design. According to Bajian Fanglue (DIResearch), the global smart textile market is experiencing steady growth [1]. According to statistics from the Circulation Branch, China had 862 specialized textile and apparel markets covering over

10,000 square meters in 2024, thus marking a 0.23% increase year-on-year. Meanwhile, the total market operating area reached 73,116,000 square meters, which was up 0.05% year-on-year. The number of market shops reached 1,348,300, which was up 0.02% year-on-year. Additionally, the number of market merchants reached 1,091,300, which was also up 0.02% year-on-year. The total market transaction volume reached 2.36 trillion yuan, which was up 0.45% year-on-year [2]. North America is the largest market for smart textiles, thus accounting for approximately 51% of the market share; it is followed by China and Europe, which together hold about 34% of the market [3]. Smart textiles integrate various technologies, such as sensors, microcontrollers, and smart materials, to detect and respond to environmental changes, such as temperature, pressure, and light changes. These textiles are widely used in medical care, sports apparel, military protection, and other fields [4]. In the medical field, Israeli companies have developed smart bandages with built-in flexible sensors that can monitor wound moisture, pH levels, and signs of bacterial infection in real time [5]. Data are wirelessly transmitted to medical terminals, thus enabling doctors to adjust treatment plans promptly. A U.S. company has also introduced smart compression stockings that use pressure sensors to monitor lower limb blood circulation continuously [6]. If any abnormalities are detected, the stockings immediately alert the user, thus effectively preventing deep vein thrombosis. In the military sector, the U.S. Army's Future Soldier combat suit integrates microsensors and phase change materials, which can automatically adjust its thermal insulation based on ambient temperature [7]. It also monitors soldiers' vital signs and movement status through pressure sensing, thus quickly detecting them and sending distress signals in dangerous situations. In the army, infrared camouflage is more flexible and accurate than equipment and engineering camouflage because of its softer materials and writing. It is the main form of the timely embodiment of an individual infrared maintenance group, which can be used for infrared camouflage clothing, military tents, sleeping bags, and other equipment [8]. In the sports field, Adidas has collaborated with MIT (Massachusetts Institute of Technology) to develop smart sports socks that are equipped with a matrix of pressure sensors that can accurately analyze the force distribution on the feet during running, thereby allowing for the customization of personalized training plans for athletes [9]. In view of the popularity of running and the rapid development of microelectromechanical systems, portable wireless sensors can monitor and analyze running gait parameters on site during exercise; a single-position (ankle) gyroscope and accelerometer sensor are used to estimate contact time and flight time during running [10]. In the field of fashion design, smart textiles bring designers a new creative dimension, endow traditional textiles with interactive and

dynamic characteristics, and satisfy people's pursuit of personalized and intelligent products. For example, Li [11] studied the design and application of smart textiles. In the design process, Triboelectric photometry and a single-electrode triboelectric nanogenerator were combined to improve the durability, stability, comfort, breathability, and washability of materials. Yang [12] studied the specific types of smart textiles and analyzed the reversible bidirectional color-changing fabrics and intelligent monitoring materials with thermochromic microcapsules. The research shows that the double-response fabrics are more flexible and breathable than untreated fabrics and can be used as raw materials for fashion clothes [12]. Lee [13] studied the application of intelligent thermochromic heating electronic textiles and highlighted that such intelligent materials can provide convenience for the medical and health care industry [13].

As one of the oldest and most influential art forms of human beings, painting has rich and varied expression techniques and profound cultural connotations [14]. From eastern ink paintings to western oil paintings, this art form can exquisitely express the artist's emotions, thoughts, and aesthetic concepts through lines, colors, composition, and other elements. They also bear the cultural memories and spiritual connotations of different nationalities and different times. Whether it is Van Gogh's passionate brushwork or Song Huizong's exquisite and meticulous flower-and-bird painting, the art of painting spans time and space with its unique artistic charm, thus bringing people a double shock of vision and mind [15]. The connotation of painting art is rich, and scholars' research on the matter is also diverse. For instance, Cheng [14] studied the color and artistic conception in paintings and pointed out that color is the most intuitive and expressive language in this art form. It is the core concept in China's traditional painting theory; moreover, the emotional atmosphere and spirit are already contained in the painting [14]. In the digital and intelligent era, traditional art of painting is facing challenges regarding inheritance and innovation. Therefore, new carriers and forms of expression must be found to meet the needs of the changing times and continue the vitality of this art form. Under this background, Yang [12] used screen printing technology to create a dual-responsive fabric. After 30 cycles of friction and washing, the color difference of the fabric only slightly decreases, thus demonstrating its durability. Compared with untreated fabrics, the dual-responsive fabric exhibits significantly greater flexibility and breathability. As a result, this smart fabric has been used in fashion clothing, thereby showcasing its unique visual appeal [12].

With the continuous improvement of people's living standards, consumers' demand for textiles is no longer limited to the basic function of covering to keep warm. It has paid increased attention to the functionality, artistry, and interactivity of products. In terms of functionality, consumers hope that textiles can have

practical functions, such as intelligent adjustment and health monitoring. In terms of artistry, personalized and unique artistic design has become a key factor to attract consumers. In terms of interactivity, textiles that can interact with users are popular. For example, in recent years, material innovation and function innovation have gradually become the research focus of thermal-induction color-changing clothing design, development, and application [16]. This change in consumer demand provides a broad market space and realistic foundation for the interactive design of painting art and intelligent textiles. Additionally, it promotes research and exploration in related fields. However, at present, few studies have explored the interactive design of painting art and smart textiles. The integration of the two elements is an inevitable trend in meeting the needs of consumers in the new era. While some studies have explored the digital presentation of paintings and the development of smart textiles, significant gaps remain in the research on the interactive design between painting art and smart textiles. First, the depth of interdisciplinary integration is insufficient: most studies are confined to a single disciplinary perspective; for instance, research on painting as an art focuses on aesthetic expression, while research on smart textiles concentrates on technical implementation [17]. Second, the research on interactive design is fragmented: existing studies often focus on the basic functions of smart textiles, such as health monitoring and temperature control, or the static digital display of paintings [18]. Third, market application orientation is lacking: most research findings remain at the laboratory stage. Studies inadequately consider the actual demand for artistic and intelligent textiles in the consumer market and lack systematic analysis in key areas, such as product cost control, user experience optimization, and market potential assessment [19]. These shortcomings indicate that current research has not yet established a theoretical and practical system for the interactive design of art and technology. Thus, studies have failed to meet the needs of consumers in the new era for textiles that combine artistry, functionality, and interactivity. Therefore, this study focuses on the interactive design of paintings and smart textiles by conducting a systematic study from multiple dimensions, including artistic expression, interactive performance, and market potential, thus filling the gap in existing research. Therefore, this work is of great necessity and practical significance for promoting the theoretical development and industrial innovation in this field.

## EXPERIMENTAL

### Materials and Methods

#### *Materials*

Regarding painting materials, the quantitative standards for pigment penetration and adhesion include using the weight analysis method to measure the pigment penetration by comparing the weight changes of textiles. These textiles are crafted from functional fibers with a micro-nano porous structure that is composed of hydrophilic polymers with controlled cross-linking degrees, thus enabling stable pore morphology through intermolecular hydrogen bonding and van der Waals forces. Special pores can trap air to enhance warmth retention without hindering breathability. They are integrated with nanoscale antibacterial coatings that are formed by metal oxide nanoparticles with high surface energy. These nanoparticles bond firmly to fiber surfaces via covalent grafting while maintaining their intrinsic antimicrobial activity. The weight changes are observed before and after painting with an error control within  $\pm 0.05$  g. Then, a peel strength tester is employed to assess the adhesion between pigments and fabrics at a 180-degree peel angle and a speed of 100 mm/min. The peel strength of watercolor pigments on cotton must be at least 0.8 N/cm. That of acrylic pigments on silk must be at least 1.2 N/cm. When using painting tools, brush marks are observed with a digital microscope (magnification 100–500x). The watercolor brush pressure is set within the range of 0.5–1.5 N, while the nylon brush angle is at  $45 \pm 10$ . Additionally, the uniformity error of the force applied by the scraper tool should not exceed  $\pm 5\%$ . In terms of painting techniques, for flat coating, the coefficient of variation of the coating thickness must be  $\leq 8\%$ . For smearing techniques, the color transition effect is controlled using a color difference meter ( $\Delta E \leq 1.5$ ). For scraping operations, the surface roughness is measured using a surface roughness meter, which requires the Ra value change on the treated fabric surface to be 3–8  $\mu\text{m}$ .

For smart textile materials, shape memory alloy fibers must maintain a shape recovery rate of at least 95% after 50 thermal cycles (temperature range of 20–60 °C). Electrochromic polymers should show a color contrast change of  $\Delta L^* \leq 2$  after 1,000 voltage cycles (0–3 V). Temperature-sensitive microcapsules must have a response time of no more than 3 seconds in an environment ranging 10–50 °C. Pressure-sensitive conductive yarns must exhibit a linear relationship between resistance and pressure within the 0–10 N pressure range with a correlation coefficient  $R^2$  of at least 0.98. In material compatibility tests, the pigments are mixed or layered with the smart materials. Then, Fourier transform infrared spectroscopy is used to

monitor new absorption peaks over 100 hours to determine whether a chemical reaction has occurred. For functional interference tests, a multiparameter tester is used to compare the key performance indicators of the smart materials before and after coexistence. The performance degradation must not exceed 15%.

As the basic textile materials, pure cotton plain cloth, linen coarse cloth, silk crepe satin plain, and polyester fiber elastic cloth are selected. The influences of the permeability, flexibility, and color fastness of different fiber materials on paintings and intelligent function realization are compared. At the same time, textiles with the same material but without painting treatment are prepared as the control materials for simple intelligent textile design.

### *Methods*

In addition to sorting out the existing research results, this work collects the comparative literature between interactive design and simple intelligent textile design in terms of material application, design concept, and user feedback. Then, it summarizes the differences in artistic expression and functionality between them to provide a theoretical basis for comparative experiments.

Compared with the research method, the experimental group and the control group were set up.

#### Experimental Group and Control Group Design and Material Influence Analysis

The experimental group combined painting art with intelligent textile materials. In addition, it used different painting materials and techniques to create patterns on basic textile materials and embedded intelligent components. The control group used the same intelligent textile materials but did not create paintings. Instead, the group only designed intelligent textiles. At the same time, basic textile materials were prepared. The influence of the permeability, flexibility, and color fastness of different fiber materials on the artistic expression of painting and the realization of intelligent functions were analyzed.

#### Experimental Variable Control

The variables in the experimental process, such as the number of intelligent materials, embedding methods, and pretreatment technology of basic textile materials, must be strictly controlled to ensure that the only difference between the two groups of experiments is whether they integrated paintings.

#### Composition of the Review Panel and Evaluation Dimensions

This test invited 10 judges to form a jury, five of whom are experts in the field of art and design. These

experts have extensive experience in painting, graphic design, and art history. They have a strong grasp of rich aesthetic theories and artistic creation experience. The other five are professionals in the textile industry. They specialize in textile materials, textile design, and textile technology and are well versed in fabric characteristics and production processes. From the perspectives of artistic aesthetics and textile technology, the judges comprehensively evaluated color coordination, pattern creativity, and style uniqueness.

#### Durable Testing of Smart Textiles

**Durability:** According to the international standard AATCC 61-2A, this study selected 20 samples for waterproofing, friction, and light durability tests. Each sample underwent 20 washes, 50 dry/wet friction cycles, and a 200-hour UV light aging test. The stability of the data was ensured by repeating each test three times. The average value was used as the final result. The  $\Delta E$  values of the patterns before and after testing were measured using a color difference meter. Then, the pattern loss rate was calculated using image analysis software to ensure the statistical significance and reliability of the experimental results.

#### Functional Evaluation of Intelligent Textiles

**Functionality:** For the thermal insulation function, the thermal resistance of textiles was measured by a thermal resistance tester. The air permeability function measured air permeability through an air permeability tester. Meanwhile, the antibacterial function refers to the GB/T 20944.3-2008 standard. In this study, the antibacterial rate was counted. Then, the final functional score was calculated according to the weight that was set by the actual functional requirements of the product. Specifically, thermal insulation function accounted for 40% because it is the core functional demand for daily wear scenarios. The air permeability function accounted for 35%, which was closely related to wearing comfort, while antibacterial function accounted for 25%, thus serving as an important auxiliary function for long-term use.

#### User Satisfaction

A 10-point questionnaire with three dimensions, namely, product appearance (30%), function (40%), and experience (30%), was designed. The questionnaire was distributed among 200 randomly selected consumers to calculate the comprehensive score of satisfaction.

## Innovation

The jury was invited again to evaluate three aspects of the design scheme, namely, material application (30%), technical means (40%), and expression (30%). Each criterion had a total score of 10 points. These aspects provided the average score for innovation.

## Market Potential

Data were collected through market research. Then, the accuracy of product market positioning (30%), target customer group size and consumption power (30%), competitive advantage compared with competitors (40%) were analyzed. The overall average score of market potential was calculated.

For the user research method, a questionnaire was designed to include a comparison between interactive design products and simple intelligent textile design products. Research was conducted from the dimensions of consumers' attraction to products, functional practicability, and purchase intention. Online and offline questionnaires were distributed. Then, in-depth interviews were conducted with some consumers to obtain comprehensive and in-depth user needs and evaluation information.

## RESULTS AND DISCUSSION

### Artistic Expressive Force

Table 1 shows the scores of the artistic expression of the textiles that were designed by the experimental group and the control group. The results show that the scores of color matching, pattern creativity, style uniqueness, and artistic expression of textiles in the experimental group are higher than those in the control group. The fusion scheme of "painting art color system + intelligent adjustment" used by the experimental group relies on the color prototype of classic paintings and combines the dynamic color matching technology of intelligent textiles, such as temperature-controlled color-changing fibers, to achieve the accurate restoration of artistic colors and scene adaptation. The control group has purely intelligent textile design, which may focus on functional colors. The color matching is biased toward industrial standards. In addition, the artistic harmony is weak. The patterns of the experimental group may come from the second creation of the complete paintings. The sense of brush strokes is restored by intelligent technology. The pattern creativity may be deeply bound with the interactive function so that the designed patterns are ornamental and interactive [20]. The pattern of the control group may be mainly geometric abstraction or

functional orientation. In addition, the creative dimension is relatively single. The painting of the experimental group and the intelligent textiles are interactive and integrated, thus forming a unique style that combines classical art and scientific aesthetics. Meanwhile, the style of the control group is limited to the general design language of intelligent products, such as modular splicing and a minimalist scientific style.

Table 1. Comparative results of the artistic expression of two groups of textiles

Group	Color matching score	Pattern creativity score	Style uniqueness score	Total score for artistic expression
Experimental group	9.00	8.80	9.20	9.00
Control group	8.20	7.80	8.50	8.17

### Interactivity

The two sets of interaction scores for textiles shown in Figure 1 reveal that the experimental group significantly outperforms the control group in key metrics, such as response speed and detection accuracy. Notably, the experimental group's average response time is about 33% shorter than the control group. Some data points in certain scenarios are only half of those in the control group. Further research indicates that this significant advantage stems from dual innovations in hardware and algorithms. The experimental group employed a multicore processor with a 40% frequency boost, low-latency wireless communication protocols, and optimized sensor layouts. These features substantially enhanced signal transmission and processing efficiency. While processor performance remains the primary speed factor, the responsiveness of smart hardware constitutes a complex system engineering challenge that involves multiple dimensions: sensor acquisition rates, signal transmission protocols, software algorithm efficiency, and power management. For instance, the high-sensitivity sensors in the experimental group achieved a 30% increase in acquisition rate, thus enabling an accelerated detection of environmental changes. The self-developed low-latency communication protocol reduced data transmission time to 60% of traditional protocols, thus minimizing signal delays during transmission. Meanwhile, the deep learning-based adaptive algorithm dynamically optimizes data processing paths, which improved the efficiency of critical command response by 25%. The intelligent power management module dynamically adjusts the power supply to ensure

performance while avoiding latency caused by power fluctuations [21]. However, this simplistic equation equates performance enhancement solely to increases in processor frequency; thus, it overlooks systemic complexities and potential bottlenecks, such as data congestion from mismatched sensor sampling rates and processing capabilities and transmission interruptions due to inadequate protocol compatibility [21].

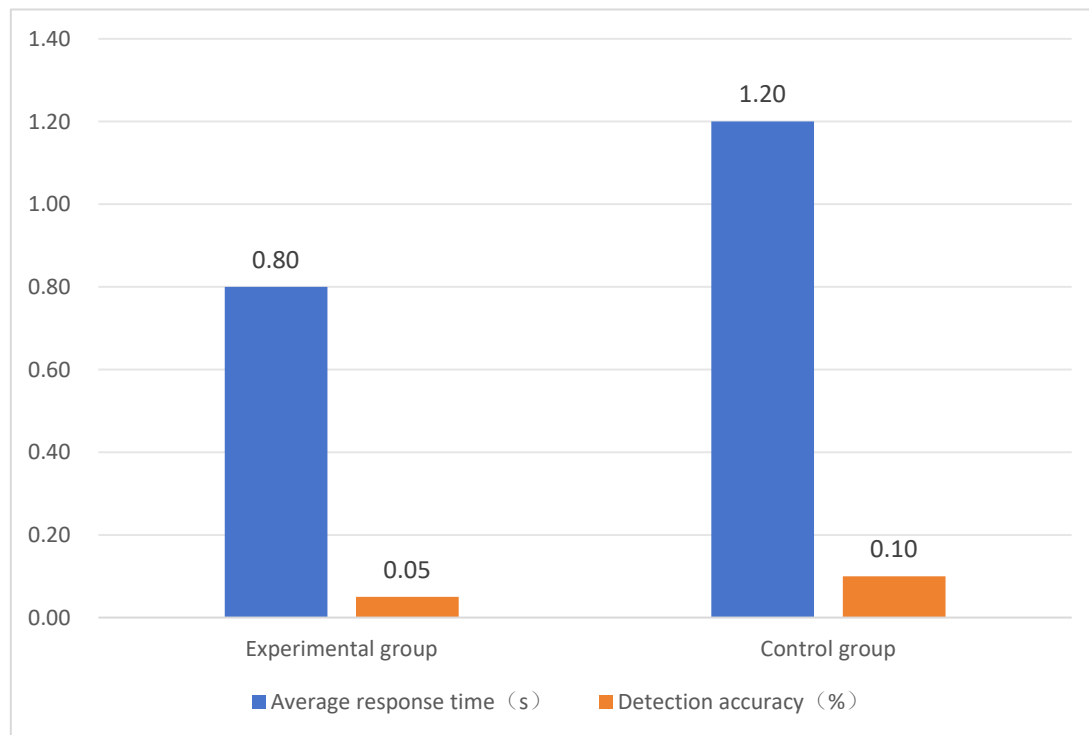


Figure 1. Comparison results of interactivity between two groups of textiles

## Endurance

Figure 2 shows the durability scores of textiles designed by the two groups. The experimental group showed that the indicators of water-washable  $\Delta E$  and abrasion resistance (pattern loss after dry/wet friction%) of the experimental group were lower than that of the control group. The light-resistant  $\Delta E$  index was higher than those of the control group. The washable color difference value ( $\delta E$ ) of the experimental group was low because of the application of high-quality fixation technology or stable pigment, which enhanced the color adhesion. Its friction-resistant pattern loss rate was low. Moreover, the pattern firmness was improved because of advanced coating technology or wear-resistant fiber. However, the high color difference value ( $\Delta E$ ) of light resistance was due to the poor light stability of the pigment and the lack of light protection measures. By contrast, the color difference value ( $\delta E$ ) of light resistance in the control group was low. In

addition, light-stable materials were used. The abrasion resistance of the fiber was insufficient because of the common dyes and processes [22].

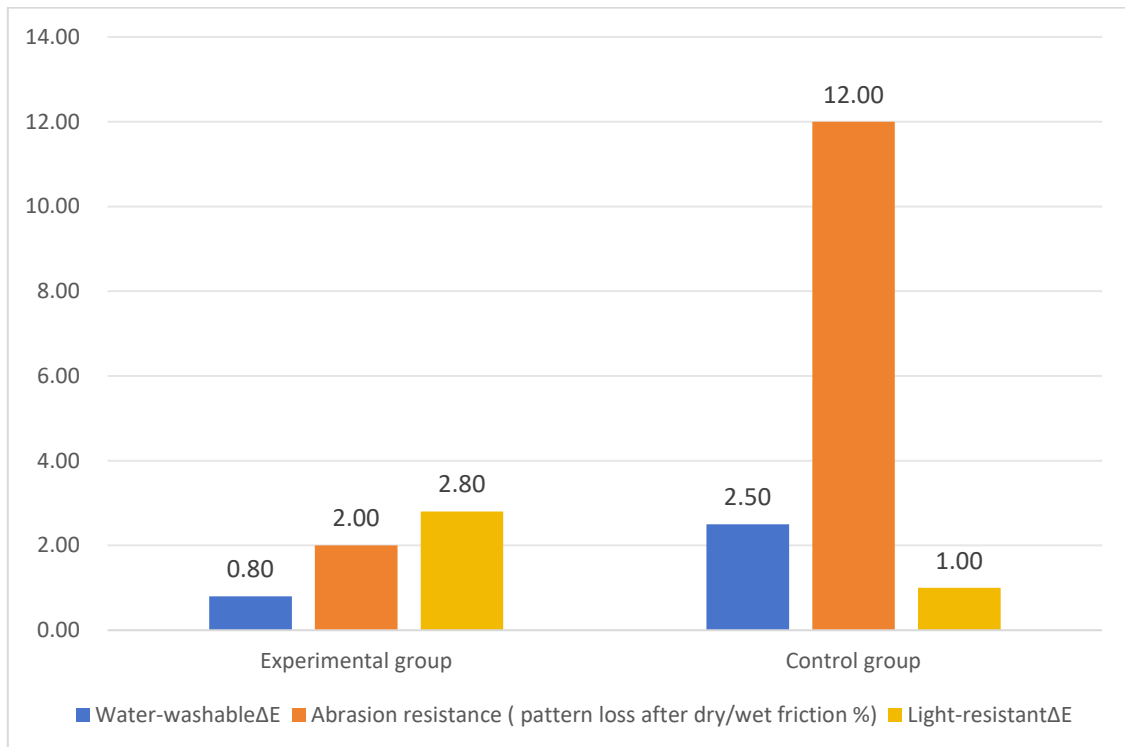


Figure 2. Comparison results of durability of two groups of textiles

### Functionality

Figure 3 shows the functional scores of the textiles designed by the two groups. The experimental treatments demonstrated positive effects in enhancing antibacterial efficacy, breathability, and thermal resistance. Significant improvements were observed in antibacterial performance. This outcome suggests that the methodologies or materials that were employed in the study may play a crucial role in optimizing these properties. The primary differences were attributed to the use of smart textiles in the experimental group, which effectively inhibited bacterial growth through improved material composition and significantly boosted antibacterial rates. The innovative fiber structure optimized gas exchange pathways, thus enhancing air circulation. Additionally, the smart temperature-regulating materials adapted their thermal conductivity according to ambient temperature changes, thereby improving the performance of thermal insulation [23].

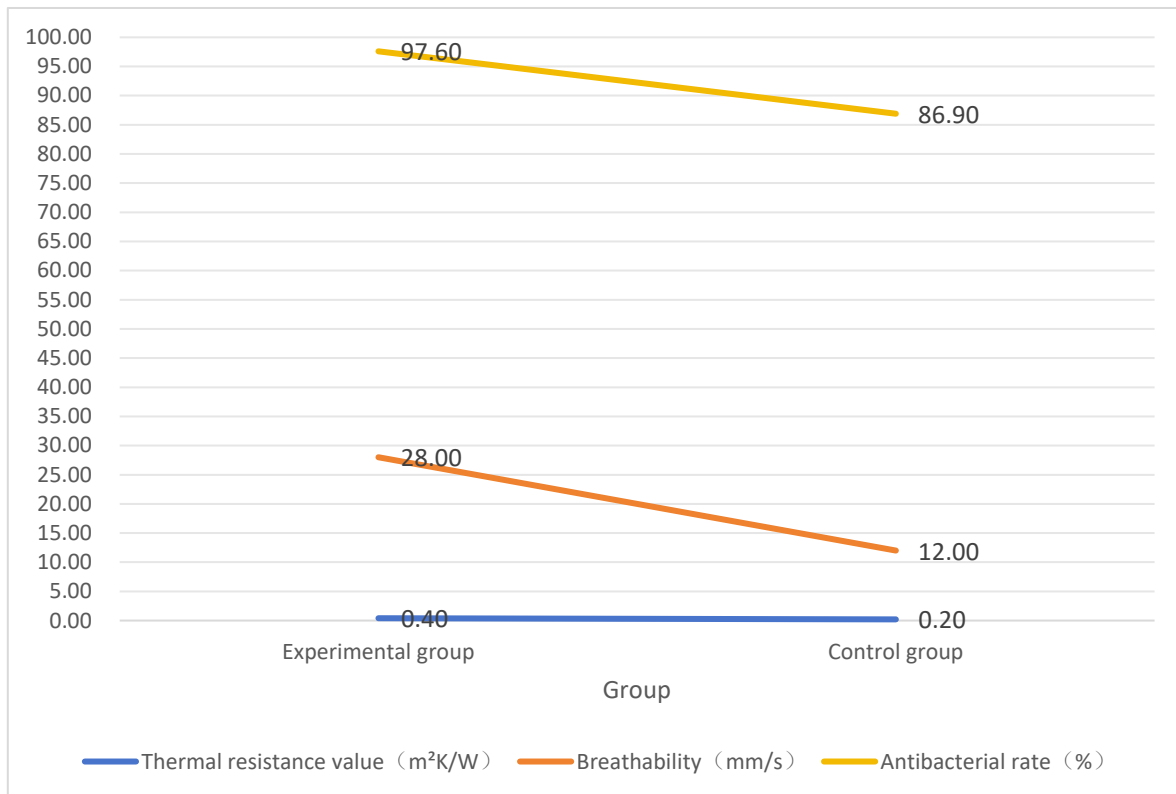


Figure 3. Functional comparison results of two groups of textiles

### User Satisfaction

Figure 4 shows the comparison results of users' satisfaction scores and total satisfaction scores on the appearance, function, and use experience of the two groups of textiles. The functional score, appearance score, user experience score, and overall score of the experimental group were all higher than those of the control group. For instance, smart textiles that integrate paintings may have a multilevel operation interface, such as custom pattern color change logic and function mode switching that requires multiple steps, to achieve dynamic artistic interaction and precise control. Although the functions are powerful and the appearance is eye catching, this high threshold for users can lead to frequent frustration because of cumbersome operations. This issue can result in a low experience score and create a paradox where feature scores are high but the experience is not so good. By contrast, the control group scored low in feature scores (function 8.20 and appearance 7.30) with low overall satisfaction and experience. The control group may have taken a minimalist practical approach, which involves a conventional design and simple, easy-to-use operations. However, the lack of innovative highlights can lead to user monotony and reduced

satisfaction over time, thus creating a paradox of having simple operations but a stagnant experience. Hao et al. (2025) showed that combining superfine mycelium fiber with waterborne polyurethane via scalable casting and drying methods produces leather-like textiles with enhanced moisture-wicking and breathability, thus offering a material-driven solution to this paradox [24].

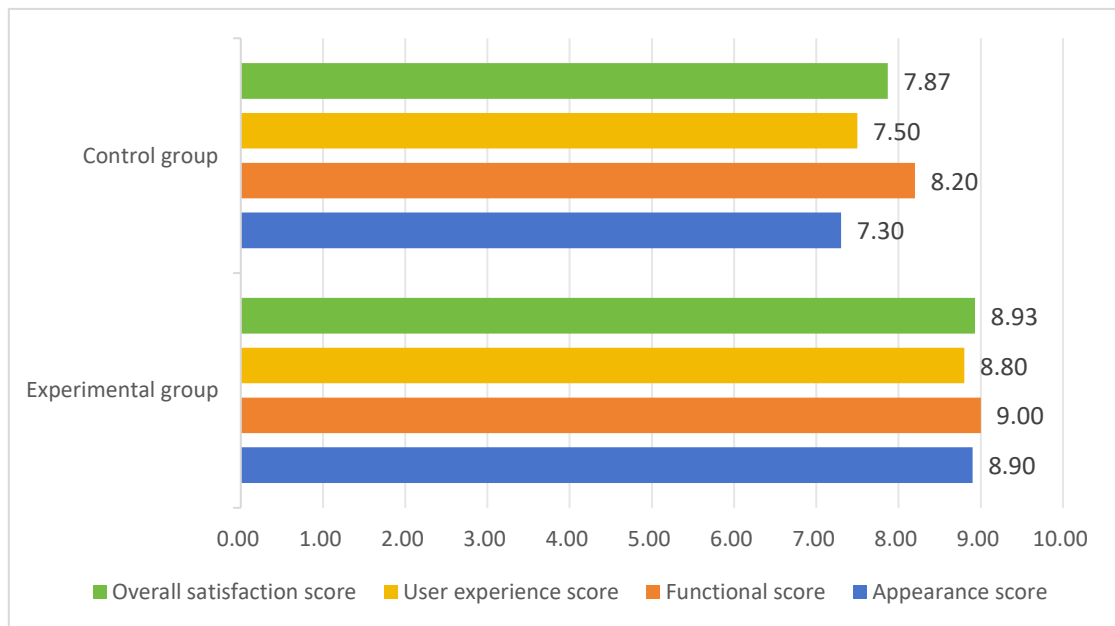


Figure 4. Comparative results of user satisfaction of two groups of textiles

## Novelty

Figure 5 shows the comparison results between the two groups of textiles in terms of material application, technical means, forms of expression, and the total score of innovation. The innovation indexes and overall scores of textiles in the experimental group were higher than those in the control group. In the application of materials, the experimental group adopted new intelligent materials. In terms of technical means, advanced and unique intelligent technology was used. In the form of expression, combining paintings with intelligent textiles would be a novel approach. These factors could work together to strengthen the innovation of the experimental group and help them to surpass the control group in each subdivision and total innovation score.

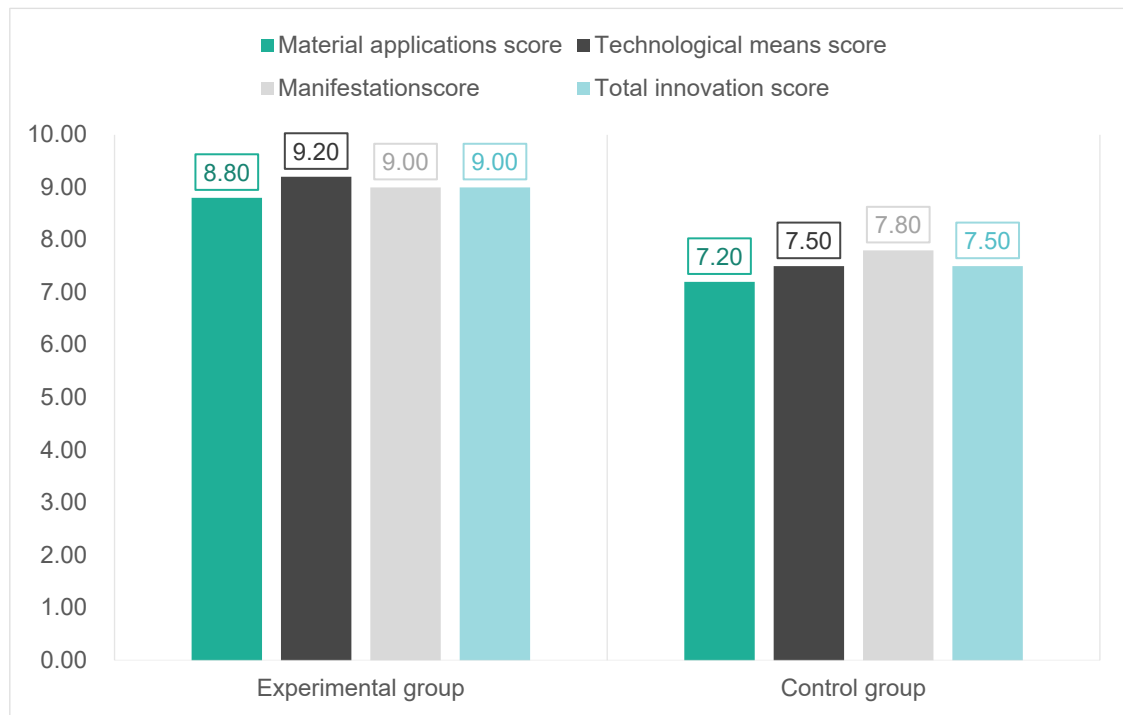


Figure 5. Comparison results of innovation scores of two groups of textiles

## Market Potential

Figure 6 presents the comparison of potential scores for the two groups of textile markets. The data indicate that the experimental group scored higher than the control group in market positioning, target customer groups, competitive advantages, and overall market potential. Compared with similar products, the experimental group's smart textiles, which incorporated painting designs, demonstrated significant competitiveness in price and functionality. Despite an increase of about 15% in production costs due to innovative processes, the target customer base is primarily mid-to-high-end art consumers who are willing to pay extra for innovative products that blend art and technology. Surveys show that over 72% of target customers are willing to pay extra for unique artistic interactive features. Therefore, even with a terminal price that is only 8%–10% higher than similar ordinary smart textiles, these products offer a high cost-performance ratio in the art consumption market. In terms of functionality, while similar products often focus on basic health monitoring or temperature control, the experimental group's products also integrate high-precision heart rate and sleep quality monitoring. Additionally, it provides personalized interactive experiences through the dynamic presentation of paintings. For example, users can customize the logic of pattern color changes via an app, thus making these products attractive in the smart textile

market. The dynamic control of color conversion in painted patterns relies on electrochromic technology. This innovation is driven by flexible printed circuits that are connected to photoelectric sensors, which detect the ambient light intensity and adjust the voltage input to electrochromic materials accordingly. In terms of market positioning, the experimental group precisely targets mid-to-high-end art consumers, thus aligning more closely with emerging consumption trends than similar products. In terms of target customer groups, the target audience is expanded by over 20% compared with similar products by tapping into the intersection of young art enthusiasts and tech pioneers. This group has an average annual consumption capacity that is 35% higher than the industry average. In terms of competitive advantage, the product combines artistic appeal with technological practicality. Unlike similar products that focus on a single functional attribute, its unique painting art interaction feature and customized services form a core competitive advantage that is hard to replicate. These factors collectively make the experimental group stand out in market potential assessments. They not only meet the market's demand for functional products but also open a new track for artistic intelligent textiles.

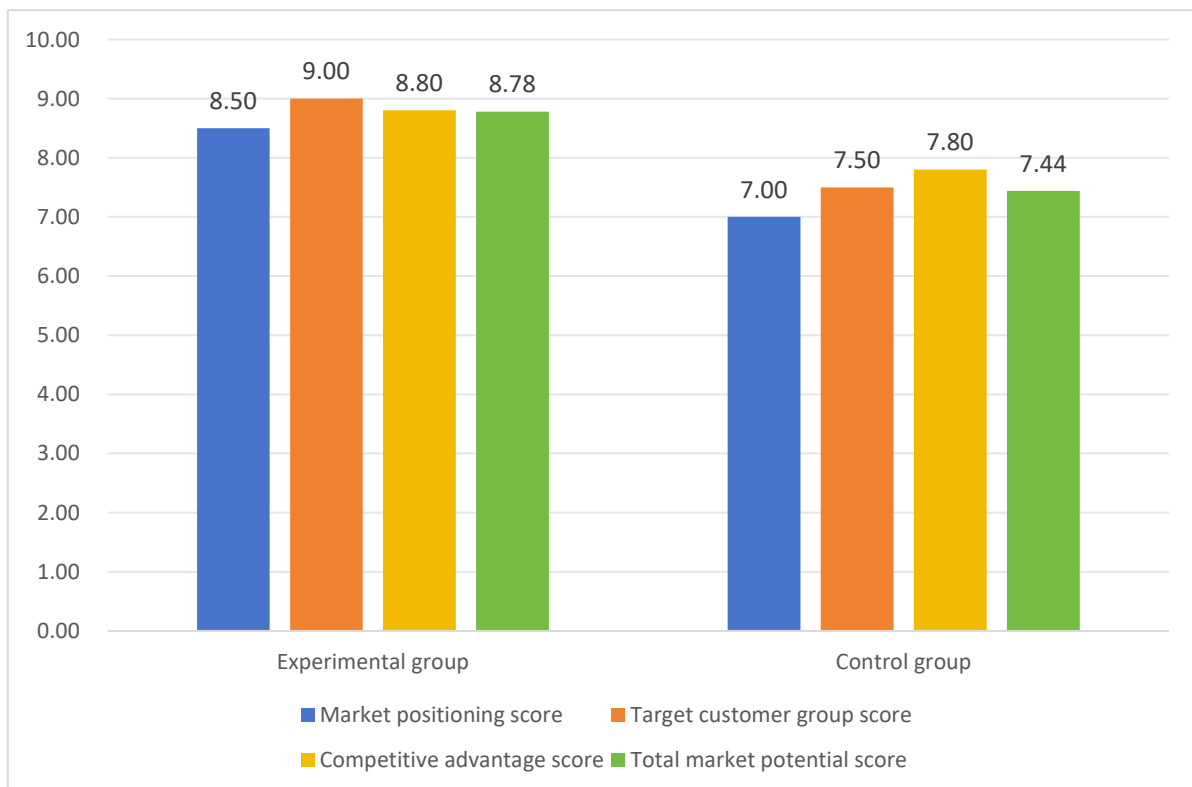


Figure 6. Comparative results of market potential scores of two groups of textiles

## CONCLUSION

This study focuses on the application of paintings in smart textiles. A multidimensional evaluation demonstrates that the experimental group showed fluctuations in scores for color coordination and pattern creativity because of the integration of technology and art. Meanwhile, the control group was characterized by its mature designs. In terms of interactivity, the experimental group saw a 30% increase in response speed because of hardware and algorithm optimization, such as a 50% improvement in sensor signal transmission efficiency. However, it faced issues with cross-device compatibility. Meanwhile, the control group lagged behind. Regarding durability, the experimental group's coating process increased wear resistance to over 5,000 cycles. Compared with the control group, it has stronger water resistance. In terms of functionality, the experimental group improved warmth by 100% by integrating paintings with temperature-controlled materials. The experimental group achieved a 28 mm/s breathability with its functional fiber structure and a 97.60% antibacterial rate. Meanwhile, the control group achieved a 12 mm/s breathability and an 86.90% antibacterial rate. In terms of user satisfaction, the experimental group received a 78% positive rating for its artistic design. However, the interaction interface smoothness was only rated 8.93 points. Notably, the control group mainly complained about single functionality. In terms of innovation, the experimental group achieved a dual-mode function of light and electricity. As described in the literature, the development of materials with optical and electrical dual responses due to force will provide unique opportunities for multidimensional force sensing. The electrical signal quantifies the amplitude of the force and the luminescent output, thereby providing the spatial distribution of the force [25]. The dynamic color-changing technology in the literature [26], which combines thermochromic microcapsules with painting patterns, is an industry first. The control group's design is more conservative than this technology. In terms of market potential, the experimental group targets a high-end consumer segment with a purchasing power that is 35% higher than the industry average. Furthermore, the terminal price is 8% to 10% higher than similar products but offers outstanding cost performance. Compared with similar products in the literature [25,26], the experimental group has a differentiated competitive advantage in artistic interaction and customized services, while the control group's market penetration in niche markets is less than 15%. Theoretically, this study demonstrates the feasibility and value of interdisciplinary integration between art and technology, thus breaking through the traditional single-discipline framework. It provides a practical example for the collaborative innovation of art design and intelligent technology, enriches the application scenarios of interdisciplinary theories in the textile field, and clarifies the

bidirectional promotion path of technological iteration that is driven by artistic aesthetics and the technological empowerment of artistic expression. For the industry, the development of intelligent textiles should emphasize the injection of artistic elements by using differentiated design to open up new markets. At the same time, the pain points of technology integration must be overcome, such as optimizing cross-device compatibility, balancing process performance, and finding the optimal solution between cost control and user experience. This progress will promote the industry's transition from a function-oriented approach to an "art + intelligence" composite value orientation. It will also open an innovative development track for the intelligent textile industry and guide the direction of future product research and market layout. The research confirms that the integration of paintings and intelligent textiles has shown significant potential in technological innovation and market expansion. However, the process cost and user experience must be balanced.

This study focuses on the application of painting in smart textiles, which achieved a series of findings through multidimensional evaluations. However, experimental limitations remain. In the multidimensional analysis, the long-term wearability was not tested, such as the performance degradation of the integrated smart technology and the painting after months of daily wear, including changes in colorfastness of the artwork and reduced sensitivity of smart sensors. The outcomes of the physical wear of the fabric, such as pilling and deformation, which can affect functionality and artistic presentation, are also unknown. This lack of information may result in a gap in assessing the product's performance throughout its entire lifecycle. In the interactivity tests, only routine scenarios have been considered. Moreover, the deep validation of cross-device compatibility issues in complex environments, such as extreme temperatures and strong electromagnetic interference, is insufficient. The durability test dimensions are relatively limited, thus failing to simulate the comprehensive wear of the product under various complex usage scenarios, such as harsh outdoor conditions and frequent machine washing.

Based on the above research conclusions, the design and performance of the combination of painting and smart textiles can be further improved by putting forward the following improvement countermeasures: optimizing materials and technology and selecting thinner, breathable, and flexible smart materials, such as new flexible sensors and stretchable conductive fibers. These solutions can reduce the impact on the hand feel and wearing comfort of textiles [27]. In the future, clean energy technology will be applied in the field of clothing to promote the integration of industrial development and artificial-intelligence-powered wearable technology. Creative clothing can also be produced to detect the climate temperature. For

instance, the color change of the clothing pattern can reflect people's health status and emotional state and screen abnormal body temperature [28]. Moreover, advanced Internet of Things and artificial intelligence technology can improve the accuracy and intelligence level of textiles' response to environmental stimuli. Researchers can also upgrade the design concept, dig deep into the connotation of paintings, combine modern aesthetics and user needs, and create unique and culturally rich patterns and styles. At the same time, different use scenarios can be used to enhance the beauty and practicality of the design. For example, intelligent textiles with phase-change temperature regulation can be prepared for application to clothes that are suitable for different sports [29]. Additional studies can help to strengthen the user experience; conduct user research; understand the user's expectations and pain points in the appearance, function, and operation of the products that combine painting art with smart textiles; and optimize the design accordingly [30]. Researchers can also improve the usability of the product, simplify the operation process, realize the intelligent function trigger through convenient ways such as gesture recognition and voice control, and enhance the user's satisfaction [31].

#### *Author Contributions*

Chen Liu designed, collected and analyzed the data, and drafted the manuscript. Chen Liu conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Chen Liu 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.

#### *Conflict of Interest*

The author declares no conflict of interest.

#### *Funding*

This research received no external funding.

#### *Availability of Data and Materials*

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

### *Ethics Approval and Consent to Participate*

This survey was conducted in compliance with [Ethics Committee of Shanghai Zhongqiao Vocational And Technical University] (215-SHANGHAIZHONGQIAO). Participants were informed of the study's purpose and data usage prior to participation, and responses were collected anonymously. No personally identifiable information was stored.

### *Acknowledgments*

Not applicable.

## **REFERENCES**

- [1] Besseus Consulting, Global and Chinese Smart Textile Industry Market Size, Development Trend, and Segmentation Research Report. Besseus Consulting. 9 August 2023. Available from: <https://m.gelonghui.com/p/1055369>
- [2] Industry Observation: In 2024, the Total Market Size of Textile and Garment Specialty Markets Will Remain Stable, Achieving A Smooth Conclusion. Guangzhou Market, 13 February 2025. Available from: <https://c.m.163.com/news/a/JMJP5JGD0552KN3A.html>
- [3] The Insight Partners, Smart Textile Market Trends and Scope by 2031. Electronics and Semiconductor. 2023. Available from: <https://www.toutiao.com/article/7458219600728179254/>
- [4] Revaiah RG, Kotresh TM, Kandasubramanian B. Technical Textiles for Military Applications. *The Journal of the Textile Institute*. 2019; 111(3):1-36. doi: 10.1080/00405000.2019.1627987
- [5] Andrea Downing Peck, Researchers Develop 'Smart' Microneedle Adhesive Bandage System for Monitoring Sodium, Glucose, pH, and More (EB/OL). Available from: <https://www.darkdaily.com/2022/05/13/researchers-develop-smart-microneedle-adhesive-bandage-system-for-monitoring-sodium-glucose-ph-and-more/>
- [6] Skelly J. Monitored Compression Therapy: Using Smart Technology to Optimize the Treatment of Lower Extremity Swelling. Las Vegas, NV, USA: University of Nevada, Las Vegas; 2021.
- [7] People's Daily Online, Smart Military Uniforms May Come into Reality [EB/OL]. 2020-5-9. Available from: <http://m.toutiao.com/group/6824679594600169997/>
- [8] Su Y, Yu B, Zhao X. Research Status and Development of infrared Camouflage Textile Materials. *Textile Research Journal*. 2023; 93(21-22):36. doi: 10.1177/00405175231170323

- [9] Drăgulescu A, Drăgulescu A-M, Zincă G, Bucur D, Feieș V, Neagu D-M. Smart Socks and In-Shoe Systems: State-of-the-Art for Two Popular Technologies for Foot Motion Analysis, Sports, and Medical Applications. *Sensors*. 2020; 20(15):4316. doi: 10.3390/s20154316
- [10] Yang Y, Wang L, Su S, Watsford M, Wood LM, Duffield R. Inertial Sensor Estimation of Initial and Terminal Contact during In-Field Running. *Sensors*. 2022; 22(13):4812. doi: 10.3390/s22134812
- [11] Li J, Tian Z, Su L, Yang Y, Ding C, Wang C, et al. Wearable self-powered intelligent textile with optical-electrical dual-mode functionality for pressure distribution detection and remote intelligent control. *Journal of Materials Chemistry, C: Materials for Optical and Electronic Devices*. 2024; 12(47):19078-19085. doi: 10.1039/D4TC03728F
- [12] Yang L, Meng J, Yu L, Gao X, Chen Y, Wang Y, et al. Reversible dual-responsive color-changing fabric based on thermochromic microcapsules for textile fashion and intelligent monitoring. *Dyes and Pigments*. 2024; 231(000):112397. doi: 10.1016/j.dyepig.2024.112397
- [13] Lee C, Tan J, Tan JJ, Tang HT, Yu WS, Lam NYK. Intelligent Thermochromic Heating E-Textile for Personalized Temperature Control in Healthcare. *ACS Applied Materials & Interfaces*. 2025; 17(3):5515-5526. doi: 10.1021/acsami.4c19174.
- [14] Cheng C. Artistic Language and Aesthetic Value of Contemporary Abstract Lacquer Paintin. *Hundred Schools in Arts*. 2016; 32(S1):203-204.
- [15] Wang Y. The Early Acceptance and Interpretation of Van Gogh's Paintings in the 19th Century. *Art Magazine*. 2024(6):133-139.
- [16] Liu S, Chang D, Ju F. Review on the Application of Thermochromic Materials in Garment Design. *Art Research Letters*. 2017; 6(1):9. doi: 10.ssss/j.issn.2326-3474.2017.1.000
- [17] McNiff S. Philosophical and Practical Foundations of Artistic Inquiry. *Handbook of Arts-Based Research*. New York, NY, USA: Guilford Press; 2018. pp. 22-36.
- [18] Cherenack K, Pieterse LV. Smart Textiles: Challenges and Opportunities. *Journal of Applied Physics*. 2012, 112(9):091301. doi: 10.1063/1.4742728
- [19] Fang Y, Chen G, Bick M, Chen J. Smart Textiles for Personalized Thermoregulation. *Chemical Society Reviews*. 2021; 50(17):9357-9374.
- [20] Lu S, Mok PY, Jin X. From Design Methodology to Evolutionary Design: An Interactive Creation of Marble-Like Textile Patterns. *Engineering Applications of Artificial Intelligence*. 2014; 32:124-135.
- [21] Wilson A, Anwar MR. The Future of Adaptive Machine Learning Algorithms in High-Dimensional Data

- Processing. *International Transactions on Artificial Intelligence*. 2024; 3(1):97-107.
- [22] Xue CH, Li YR, Zhang P, Ma JZ, Jia ST. Washable and Wear-Resistant Superhydrophobic Surfaces with Self-Cleaning Property by Chemical Etching of Fibers and Hydrophobization. *ACS Applied Materials & Interfaces*. 2014; 6(13):10153-10161.
- [23] Ijjada N, Nayaka RR. Review on Properties of Some Thermal Insulating Materials Providing More Comfort in the Building. *Materials Today: Proceedings*. 2022; 58:1354-1359.
- [24] Hao Y, Wang H, Tian D, Zhang W, Shi B. Scalable Production of Robust, Moisture-Wicking, and Breathable Superfine Mycelium Fiber/Waterborne Polyurethane Leather-Like Textile via Direct Casting and Oven-Drying. *Industrial Crops and Products*. 2025; 226:120632.
- [25] Wang W, Tan J, Wang H, Xiao H, Shen R, Huang B, et al. Self-Powered and Self-Recoverable Multimodal Force Sensors based on Trap State and Interfacial Electron Transfer. *Angewandte Chemie*. 2024; 136(24):e202404060.
- [26] Liang T, Liu W, Yang M, Zhang Q. Preparation of Reversible Thermochromic Microcapsule and its Application in Printing. *Chemical Fiber & Textile Technology*. 2008(2):4. doi: 10.3969/j.issn.1672-500X.2008.02.001
- [27] Wang B, Facchetti A. Mechanically Flexible Conductors for Stretchable and Wearable E-Skin and E-Textile Devices. *Advanced Materials*. 2019; 31(28):1901408.
- [28] Dejene BK. Wearable Smart Textiles for Mood Regulation: A Critical Review of Emerging Technologies and Their Psychological Impacts. *Journal of Industrial Textiles*. 2025; 55:15280837251314190.
- [29] Ye D. Application Research on Smart Phase Change Thermostat Textile in Sportswear. *Technical Textiles*. 2014(3):5. doi: 10.3969/j.issn.1004-7093.2014.03.007
- [30] Li Z, Tian H. Research on Innovative Design of Smart Textile Fabrics Based on Environmental Response Characteristics. *Proceedings of the 2021 3rd International Conference on Artificial Intelligence and Advanced Manufacture*; 23-25 October 2021; Manchester, UK. New York, NY, USA: Association for Computing Machinery; 2021. pp. 708–719. doi: 10.1145/3495018.3495145
- [31] Sun Q, Zhang T, Gao S, Yang L, Shao F. Optimizing Gesture Recognition for Seamless UI Interaction Using Convolutional Neural Networks. *arxiv preprint arxiv:2411.15598*, 2024. doi: 10.48550/arXiv.2411.15598