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Mixed Reality Empowerment: Innovative Applications in the Field of Industrial Design Education

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Abstract: As an emerging force born in the 19th century, industrial design has continuously embraced and integrated cross-field elements, gradually evolving into a complete system. With the advent of the new era of Industry 4.0, emerging technologies such as virtual reality, augmented reality, and interactive technologies have been booming. The integration of intelligent technologies into industrial design has emerged as a significant contemporary issue. With the expansion of the industrial designer team, the defects in the field of industrial design education have become increasingly exposed. This paper focuses on the deficiencies in the field of industrial design education. Firstly, it explores the connotations and current situations of industrial design and mixed reality disciplines. Furthermore, it proposes three educational means of integrating mixed reality technology: building an interactive design platform, developing a new AR - CMF real - time projection software, and constructing a DIY experience platform for product innovation design. These means aim to enhance the interactivity, convenience, and efficiency of education, and at the same time promote collaboration and learning between teachers and students.

Keywords: Industrial Design Education, Virtual Reality, Augmented Reality, Mixed Reality, Interactive Technology

1. Introduction

Industrial design is a process in which industrial designers utilize their imagination and innovative thinking, combine life experiences, art, engineering principles, etc., to design creative products with unique appearance, structure, and function, and then commercialize these concepts for production [1]. Compared with the single - product design in the traditional industrial design industry, the current industrial design industry has given rise to multiple branches such as UI design, human - computer interaction design, visual communication design, and animation special effects rendering. As a result, the employment channels for industrial designers have been increasingly broadened. In this rapidly changing and cross - integrated innovative ecosystem, industrial designers must possess qualities such as cross - disciplinary integration, good communication skills, innovative thinking, and the ability to keep up with the times. They should be bold enough to draw on advanced technologies from other industries and design more stunning, intelligent, and trendy products.

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2. Overview of Virtual Reality Technology

Virtual reality (VR) technology is a technology that creates a virtual environment through computer technology, integrating cutting - edge achievements in multimedia, human - computer interaction, display technology, simulation technology, etc. It provides users with a full - range of sensory experiences such as vision, touch, and hearing, enabling users to obtain an immersive experience [2]. This technology encompasses several key sub - fields, including stereoscopic display, scene modelling, and natural interaction technology. VR display technology is one of the indispensable technologies for realizing the VR experience. It directly affects the user's sense of immersion and interactive experience, including technologies for generating vision, force, touch, and smell, which are achieved through devices such as head - mounted helmets, VR glasses, data gloves, and force - feedback devices.

VR technology is booming and gradually embarking on a path of cross - integration with other fields. In the military and medical fields, VR technology has great potential. It can be used for the psychological adjustment of front - line combatants, combat casualty rescue training, and triage, and can also be applied to the treatment of PTSD, acquired brain injuries of medical rescue personnel in the rear, and the rehabilitation treatment of disabled soldiers [3]. Huang et al. focused on shield tunnel construction, used Unity3D technology to construct a virtual panorama of the construction site, displaying the geological information and prediction results of the tunnel area, providing information support for promoting shield construction [4]. Zhao et al. started from theory, expounded on the application of VR - assisted vestibular rehabilitation training for various types of medical patients, attempting to provide academic reference for relevant researchers [5]. In the tourism and cultural heritage fields, VR technology can provide immersive tourism experiences and virtual reproductions of cultural heritage. The virtual reality museum of Shaanxi History Museum is a vivid example. The museum provides tourists with a virtual tour centered on the history of ancient Shaanxi civilization, allowing tourists to immerse themselves in experiencing the historical heritage of the ancient capital of thirteen dynasties.

Looking at the education field, Zhao et al. developed a caries identification software based on the UniDental system, hoping to complement traditional ex - vivo tooth teaching and assist in stomatology teaching [6] . Zhang et al. attempted to apply mixed reality technology to the construction of a virtual teaching system for monitors, providing a reference for medical device teaching and training [7]. However, research and exploration on the integration of VR technology industrial design education are still scarce. It is urgent for scholars to deeply understand the deficiencies in the field of industrial design education and propose innovative solutions targeted at them, providing a template for the innovation of industrial design education.

3. Overview of Virtual Reality Technology

Augmented Reality (AR) technology is a technique that uses computer technology to superimpose and integrate virtual information with the real environment, enabling the co - existence and co - prosperity of the virtual and real worlds [8]. It is not merely about overlaying virtual objects onto the real environment but also an expansion of the senses, allowing users to understand the surrounding environment more intuitively and enriched.. Passing a cake shop and encountering both the visual display of cakes and the enticing aroma exemplifies augmented reality.

The application of AR technology in museum learning is a hot topic at present. According to existing literature, the most common application of AR technology is the combination of mobile devices and guided tours [9]. This combination not only enriches the guided tours to a great extent but also enhances the interaction between visitors and history.

The key to the realization of AR technology lies in display devices and projection technology. Display devices include Optical See - Through Head - Mounted Displays (OST - HMD), Video See - Through Head - Mounted Displays (VST - HMD), and Stereo See - Through Head - Mounted Displays (S - HMD) [10]. Among them, the Optical See - Through Head - Mounted Display (OST - HMD) uses the principle of optical reflection to superimpose the illumination of the real scene and the virtual scene, achieving augmented reality. This technology has shown great promise in the military field, enabling soldiers to obtain a broader field of vision and even night - vision capabilities. Projection - based augmented reality directly projects virtual images or videos onto the surface of objects to achieve the effect. This technology is commonly seen in games, education, and even daily life. Whether it is to enhance the interest in education or the immersion of games, it can bring an unprecedented experience.

4. Deficiencies in the Field of Industrial Design Education

Skills such as hand - drawing, 2D graphic design, 3D modeling, and rendering are essential for industrial designers to master proficiently. Designers should also possess good aesthetic competence and keen insights into life. Currently, there are significant deficiencies in industrial design education, and there are limitations in the teaching process from hand - drawing to practice. The following paragraphs discuss the aspects with the greatest limitations.

In terms of 3D Modeling and Rendering Education, the one - to - many large - class software teaching in 3D modeling and rendering has exposed a series of challenges that urgently need to be addressed. The teacher's demonstration of modeling and rendering is a "one - time" resource, which is difficult to meet the needs of students with different learning rhythms and acceptance abilities. The "one - to - many" teaching mode also means that some students' questions cannot be solved in class, resulting in a substantial increase in the time and energy invested in after - class self - study, and a significant reduction in learning efficiency. Modeling software generally has major flaws. The complex modeling process requires students to invest a great deal of time and energy. Some software even has the fatal drawback that certain steps are irreversible. Such irreversible steps have become a major obstacle in the learning process, seriously dampening students' enthusiasm and confidence. Both the modeling and rendering processes are plagued by the problem of long time consumption. Moreover, if problems left over from modeling are encountered during rendering, it is necessary to return to the modeling software for adjustment, and the previous version of the rendering has to be abandoned halfway. Therefore, shortening the time for conceptual modeling and visualization and achieving flexible switching for the perfect modification of target objects between software have become the common aspirations of industrial designers.

Students' hand-drawing skills reveal deficiencies in color matching and light-shadow relationships. Their rendering often lacks the ability to effectively configure textures and colors to satisfy user requirements, indicating inadequate aesthetic competence rooted in insufficient foundational fine art skills.

In terms of Practice, the effectiveness of social research is often restricted by the low participation of users, which undoubtedly weakens the authority and guiding significance of the research data. Students' research mostly relies on online questionnaires and offline interviews. However, the effective recovery rate of online questionnaires is doubly restricted by students' personal networks and the effect of online promotion. The participation rate of offline interviews is influenced by various factors such as public psychology, topic attractiveness, and interaction quality. Furthermore, students often fail to assess the appearance and performance of the designed products adequately and cannot establish in - depth communication with users. The ultimate goal of industrial design is to serve the social group. If it is unable to accurately establish a relationship with the surrounding systems [12]

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and blindly pursues the gorgeous appearance unilaterally, the design will be empty and lack vitality. The practice problems reveal a core defect in industrial design education.

5. Innovative Applications of Virtual Reality in the Field of Industrial Design Education

At present, the boundaries of the integration of industrial design with multiple disciplines have not been fully expanded, which, to some extent, restricts the breadth and depth of design. More worryingly, the industrial design industry is becoming increasingly unpopular, and students majoring in industrial design tend to transfer to more sought - after majors such as mechanical engineering. With the development of science and technology and the changes of the times, traditional industrial design education can no longer adapt to the rapidly changing era. Interaction, digitization, and intelligence have increasingly become the themes of the times, and the integration with virtual reality technology has emerged as a key measure for the innovation of industrial design education. In response to the above - mentioned background and educational deficiencies, the following three innovative approaches are proposed to optimize industrial design teaching and cultivate new - type industrial design talents under a new teaching model.

5.1. Building an Interaction Design Platform

In the current era of intelligent interaction design, human-computer interaction technology serves as a pivotal force in industrial design education, showcasing remarkable potential through various interaction modalities, including gestures, voice control, VR, AR, and touchscreens. [13] build the bridge of human - computer interaction. The interaction design platform integrates gesture interaction, voice interaction, and VR interaction technologies, aiming to promote the intelligent upgrade of the industrial design teaching platform, facilitate the concept modeling and visualization processes, and at the same time, spark the collision of ideas between "future design" and "designing the future". Gesture and voice interactions enable teachers and students to communicate with the computer system through gesture actions and voice commands, while VR interaction allows teachers and students to deeply interact with the virtual environment through interactive devices, enriching the teaching experience.

In terms of VR interaction, teachers and students use the platform to conduct virtual modeling and virtual rendering through hand - held 3D interactive devices, data gloves, force - feedback devices, etc. [14], and virtually complete the entire process of industrial product design. During virtual modeling in a visual environment, teachers and students can directly modify the model design at any time through operations such as undoing, parameter adjustment, and surface modification [15], avoiding the cumbersome operations in the original software. It is worth noting that in the VR environment, teachers and students can break through the boundaries of time and space and jointly complete the design of industrial products, which effectively overcomes the one - size - fits - all drawback of traditional teaching and increases the opportunities for teacher - student interaction.

In terms of gesture interaction, the function keys required to complete any step in computer software are presented on the virtual touchscreen in the virtual environment. Teachers and students only need to touch the virtual buttons through the interactive device to switch to that step. Basic operations such as translation, scaling, and rotation of objects, components, or textures can be easily controlled by gestures. For example, after a student selects a certain component of an object, he/she only needs to make a sliding gesture in the air towards a specific direction to skillfully move the component.

In terms of voice interaction, after teachers and students select the target edge or surface using the interactive device and issue a voice command, the platform will make corresponding parameters or effect changes according to the command. For example, during the concept visualization of the

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"Caregiver" intelligent walking stick, considering the comfort and safety of the walking stick's grip ring, students should render a "raised" texture on the surface of this part and assign a material with a strong sense of comfort such as cork or silicone. At this time, the student only needs to hold the interactive device, select the specified surface of the grip ring, and issue a voice command like "Material: anti - aging silicone; Texture: grid, circular, arranged in hexagons, concave - convex", and the initial configuration of the material and texture can be easily completed. Further setting or adjustment of texture parameters can refer to the VR and gesture interaction parts, or can also be completed in the voice command. Suppose it is noticed during the visualization process that the diameter of the Non - slip Mat bottom surface of the walking stick is insufficient,. In that case, the student only needs to interrupt the visualization, use the interactive device to select the bottom surface of the Mat, and then issue a voice command "Adjust the diameter to D". This interactive method that seamlessly combines voice recognition and model editing skillfully integrates the modeling and visualization work, simplifies the operation of computer software, and can greatly enhance the design freedom.

The three human - computer interaction technologies complement each other, reducing the operation difficulty and simplifying the teaching process of industrial design. This is a major highlight of the innovative combination of human - computer interaction and industrial design education.

5.2. Developing New AR - CMF Real - Time Projection Software

The AR - based CMF real - time projection software can serve as an innovative auxiliary tool, leveraging its unique advantages to effectively enhance students' design efficiency and indirectly improve their aesthetic literacy during the dynamic iteration of CMF. The AR - CMF real - time projection software can be installed on tablets or smartphones, achieving the overlay of virtual images and real - world objects based on augmented reality technology.

The primary step in achieving AR projection is to use 3D printing technology to transform a digital model into a physical model. Students scan the physical model through the AR software, which acquires the model information through image recognition technology, thereby enabling the real - time overlay of virtual CMF information. The AR software is interoperable and has real - time connectivity with other rendering software. This allows the CMF information designed in software such as KeyShot to be imported into the AR software, ensuring that any changes made in the rendering software are reflected in real - time in the AR application. Students first need to design various CMF effects in the rendering software and then import them into the AR software to form CMF alternatives. The AR software supports connection to various AR devices. After students wear devices such as smart glasses, they can view the virtual rendering effects of the physical model in real - time. If they are not satisfied with the effects, students can directly make real - time adjustments through the virtual touchscreen, or allow others to make modifications in software like KeyShot while they observe the effects in real - time in the AR environment. In the AR software, students can click on different CMF alternatives, and the projection overlay on the model will be updated immediately, facilitating quick comparison and evaluation of multiple options.

This visual effect of virtual rendering in the AR software can provide students with real - time feedback, prompting them to further optimize the CMF attributes of the product. If students come up with multiple design solutions, this dynamic projection will accelerate the iteration of the "CMF coat" of the product prototype, reducing the time spent on CMF replacement in software like KeyShot and facilitating quick comparison of solutions. Considering that there are already software such as Keyshot with AR on the market, this paper proposes to develop different new AR - supported CMF real - time projection software based on the above content. The aim is to adapt to diverse teaching environments and create unique teaching tools for different design courses.

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5.3. Constructing a DIY Experience Platform for Product Innovation Design

Professor Liu from Tsinghua University stated that design, which elevates the human spirit, must transcend superficial elements, focusing instead on serving the majority and society [16]. The purpose of industrial design has always been to serve society. A good design product should meet the personalized needs of the vast number of users, and its designers should closely engage with users to build a win - win system among designers, users, and society. Against this backdrop, a DIY experience platform for product innovation design can be established in the field of education to avoid students' weaknesses in the practical process and lay a solid foundation for students to grow into senior industrial designers.

On the one hand, students can use the DIY experience platform to showcase, evaluate, and validate their designs, and immerse themselves in experiencing the effects of the products they designed, thus testing the results of their design practice [14]. If the product design does not meet their expectations, students can "send back" the product to the interaction design platform for virtual optimization at any stage, targeting the design flaws. This approach significantly accelerates the process of refining and polishing the product concept. At the same time, it transforms the abstract design process into a tangible and experiential practice, greatly enhancing the innovation efficiency.

On the other hand, the surveyed subjects can also use this platform to experience the design in an immersive way, and then put forward personalized design plans and improvement suggestions, making the design conform to design psychology, ergonomics, and user experience. For example, a design team developed a "peanut" barbecue grill for outdoor camping activities. During the research process, users can put on VR glasses and enter the camping scene in person to "experience" various performances of the barbecue grill, such as whether its appearance can blend well with the camping environment, whether it is convenient to disassemble and assemble, whether the size is appropriate, and whether the grilling effect satisfies them. After the "experience", users can immediately put forward opinions and suggestions, which will determine the subsequent work process of the students. User feedback is like a panacea for product improvement. This immersive approach to engaging user feedback enhances product redesign and provides a platform for students to reflect on their designs and hone their skills, ultimately improving user engagement, research efficiency, and data accuracy [17], but also effectively solves the problems students face in research.

6. Conclusion

With the increasingly prominent trend of intelligence in the industrial design major, industrial design is no longer confined to traditional mechanical design and product design. It is undergoing a transformation and integrating with computer science, artificial intelligence, big data, etc. The integration of virtual reality technology into industrial design education is an irresistible trend. Through the platforms and software in the field of industrial design education proposed in this paper, the interactivity of industrial design education will be enhanced, the educational process will become more convenient and efficient, and the visualization of concept understanding, the simplification of the design process, and the evidence - based design verification will be further strengthened. As a result, the educational experience can be greatly optimized. In this way, both teachers and students can benefit from this optimized educational model and jointly promote the continuous development of industrial design education. The innovative approaches advocated in this paper are merely a preliminary concept of the application of mixed - reality technology in the field of industrial design education. Future advancements in technology will reshape industrial design education, fostering a new generation of forward-thinking design professionals. Industrial design education also needs to keep up with the trend of the times, advance with the times, always firmly stay at the forefront of the times, and continuously and actively explore new paths of integration with advanced technologies

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such as artificial intelligence, so as to inject a continuous stream of vitality into the field of industrial design and jointly create a glorious future for this major.

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