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Research on Teaching Reform in Environmental Design Courses Based on Virtual Simulation Technology

Xin Xu*, Yizhang Li

College of Arts, Sichuan University, Chengdu 610207, Sichuan, China

**Author to whom correspondence should be addressed.*

Abstract: Addressing limitations such as the lack of immersion and difficulties in comprehensively evaluating design schemes in traditional teaching models of environmental design courses, this study explores teaching reforms using virtual simulation technology. An immersive virtual teaching environment was constructed, integrating virtual simulation technology gradually into the teaching process, with practical teaching cases used to assess the effectiveness of these reforms. Results demonstrate that virtual simulation technology significantly enhances students' spatial understanding and design expression abilities, while also improving teaching interactivity and student engagement. This reform aligns with the trend towards digital design, offering innovative ideas and methodologies for teaching environmental design courses.

Keywords: Virtual simulation; Teaching reform; Environmental design major

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1. Introduction

Traditionally, environmental design courses have relied heavily on two-dimensional drawings, renderings, and physical models to cultivate students' spatial design skills. However, these traditional methods struggle to accurately convey the true spatial scale and atmosphere of design proposals, making it difficult for teachers and students to evaluate designs effectively and immersively. This creates considerable challenges in design evaluation and optimization processes.

With the rapid advancement of digital technologies, the application of virtual simulation technology in design education has increasingly attracted attention [1], providing new avenues for teaching design courses. For instance, the Central Academy of Fine Arts in China established the "Virtual Curatorial Laboratory for Art Museums," incorporating virtual reality (VR) technology into exhibition design teaching practices [2]. Staffordshire University in the UK transformed an abandoned hangar into an extended reality (XR) laboratory, creating an interactive and immersive learning space. These practices demonstrate that virtual reality technology can significantly enhance teaching outcomes in environmental design courses by allowing students to actively explore and intuitively assess design proposals within virtual environments, thereby deepening their understanding of spatial design [3].

Compared to traditional teaching methods, VR technology facilitates the creation of immersive, interactive spaces at a realistic scale (1:1), enabling both teachers and students to experience and evaluate spatial arrangements and environmental atmospheres intuitively. Such innovative teaching approaches are beneficial for cultivating innovative design talents aligned with digital trends. This paper discusses constructing a virtual simulation teaching environment suitable for environmental design courses, presents practical applications through specific teaching cases, and analyzes the positive impacts and potential challenges encountered during implementation, along with corresponding coping strategies.

2. Design and implementation of teaching reform based on virtual simulation

Integrating virtual simulation technology into environmental design courses requires systematic planning of the teaching process and content. The general approach involves utilizing virtual reality as a medium to redesign teaching activities, enabling students to "learn by doing and simulate by learning," thus achieving immersive interaction throughout the entire process from conceptual design and presentation to evaluation and feedback [4]. The specific implementation flow is shown in **Figure 1**.

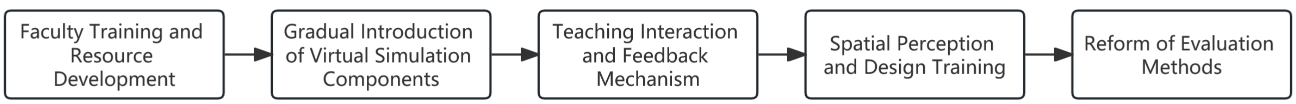

Figure 1. Teaching reform process

2.1. Faculty training and resource development

Adequate preparation, including faculty training and the development of teaching resources, is essential before implementing reforms. The teaching team should participate in virtual simulation teaching training in advance, becoming proficient in operating relevant equipment and software. Additionally, basic virtual simulation content creation training sessions should be offered to students, covering skills such as model import, scene calibration, and interactive design. Furthermore, establishing and fine-tuning a virtual simulation laboratory environment is necessary, including installing and configuring essential equipment and software, preparing basic scene templates, and providing several demonstrative virtual models for student reference. Thorough preliminary preparation helps reduce technical barriers, allowing students to focus more effectively on the design itself.

2.2. Gradual introduction of virtual simulation components

Virtual simulation tasks are gradually integrated into each teaching phase of the course. At the initial stage, students begin considering how their traditional conceptual designs can later be presented through virtual simulation. In the intermediate stage, after students complete their digital models, these models are imported into a virtual simulation platform for interim presentations. Teachers and fellow students observe each student's virtual scene demonstrations in real-time via projection equipment, engaging in interactive discussions within the immersive environment. In the final stage, students iteratively refine their design proposals while repeatedly using virtual simulations for self-review and optimization. Ultimately, an immersive virtual simulation presentation replaces the traditional oral defense for evaluating the final design outcomes.

2.3. Teaching interaction and feedback mechanism

Virtual simulation provides novel pathways for teacher-student interaction. Teachers can enter the virtual scenarios created by students to provide real-time guidance. Using VR controllers, teachers can mark problematic areas within the virtual space, allowing students to intuitively understand where modifications are needed. When conditions permit, teachers and students can simultaneously explore the same virtual environment, discussing designs as they navigate. Students can also use virtual simulation after class to personally experience their peers' design works and submit feedback. Teachers may organize "virtual visit" sessions to develop students' abilities to analyze and discuss others' designs. Additionally, teachers can invite real audiences, such as other teachers and students from the university, into the virtual exhibition space to experience the designs and provide feedback. This enables students to refine their designs based on user-centered design principles during the course.

2.4. Spatial perception and design training

Virtual simulation offers unique opportunities for spatial perception training and should be integrated into teaching to enhance students' grasp of scale and volume. Students are encouraged to regularly inspect their designs from a first-person perspective, such as exploring virtual exhibition spaces from the viewpoints of both adults and children, and assessing the friendliness of the space toward different audience groups. Such exercises foster students' habits of thinking about design from a human scale and perspective.

For example, in interior architecture courses at the University of Kansas, USA, students utilized virtual reality (VR) technology to adjust their observation viewpoint to the eye-level of young children, evaluating spatial accessibility and safety from a child's perspective. Through this immersive experience, students identified issues that were difficult to detect through traditional drawings alone, thereby optimizing their design proposals and enhancing spatial inclusivity and safety. This teaching practice illustrates an innovative application of virtual simulation technology in environmental design education, emphasizing a user-centered design philosophy [5].

We introduce similar scenarios in our course to prompt students to consider the needs of diverse user groups. Students can also leverage measurement and annotation features inherent in virtual simulation tools to directly compare data, such as corridor widths and elevation differences, against design standards, thus reinforcing their practical understanding of professional guidelines. Moreover, virtual simulations enable real-time adjustments to parameters like lighting, immediately revealing changes in spatial atmosphere, which aids in cultivating students' sensitivity to design elements and their decision-making skills.

2.5. Reform of evaluation methods

To comprehensively assess students' design achievements and overall abilities, traditional evaluation mechanisms have been reformed. The revised approach emphasizes process evaluation, documenting and incorporating students' participation and improvements during each stage of virtual simulation design into their overall grades. Outcome evaluation primarily focuses on spatial effects and the quality of immersive experiences provided by the design proposals. Evaluators are required to use virtual simulation equipment to personally experience students' final designs, assessing them based on spatial arrangement, circulation smoothness, scene authenticity, and interactive creativity [6]. Additionally, a reflective evaluation component has been introduced, requiring students to submit reflective reports detailing their experiences with the virtual simulation teaching reforms and considering the impact of virtual simulation technology on their design thinking and capability development. These reflections offer valuable insights for teachers to further enhance the teaching methodology.

3. Case study analysis

To visually illustrate the practical effects of the aforementioned teaching reforms, this study selects a teaching case from the course "Exhibition Space Design" in the Environmental Design program at the College of Arts, Sichuan University for analysis. The comparative application of VR technology across various stages of this teaching case is presented in **Table 1**.

Table 1. VR application in teaching case by stage

Teaching stage	VR application methods	Teaching outcomes
Stage 1: Technical training	Basic VR demonstrations and training	Quick adaptation, increased interest
Stage 2: Mid-term review	VR presentations and assessments	Rapid problem identification, efficient improvements
Stage 3: Refinement testing	VR user feedback for optimization	User-centric problem solving, improved designs
Stage 4: Final exhibition	Immersive VR showcase	Impressive presentation, enhanced achievement

3.1. Case background

The sophomore-level course "Exhibition Space Design" in the Environmental Design program at the College of Arts, Sichuan University required students to design a permanent exhibition hall for a digital technology museum. Traditionally, such projects have been presented using two-dimensional drawings and physical models. However, VR technology was introduced in this course to experiment with a completely new teaching approach. Students were informed from the outset that their final design projects were expected to be showcased through VR technology.

Given that most students were experiencing VR-based design expression for the first time, dedicated VR skill training was arranged during the first week. Students personally experienced a virtual exhibition walkthrough previously prepared by instructors and learned the fundamental processes of constructing VR scenes, quickly overcoming their initial unfamiliarity with VR.

3.2. Scheme design and mid-term review

During the design phase (weeks 2–6), students repeatedly tested their digital models by importing them into the VR environment while conceptualizing the exhibition layout. Through VR walkthroughs, many issues that were not easily identifiable on two-dimensional drawings became immediately apparent. For instance, one student discovered that a corridor marked as 3 meters wide appeared too narrow in VR, prompting an adjustment to 3.5 meters. Another student enhanced the presentation of exhibits by adjusting the color temperature of the lighting. Immediate feedback accelerated the design optimization process, encouraging students to proactively refine their proposals.

In the mid-term review held during week 7, VR presentations were utilized. The classroom was equipped with two sets of HTC Vive Pro 2 headsets, and students took turns delivering immersive presentations of their design schemes, while classmates and instructors simultaneously observed the presenter's first-person view on a projection screen. Reviewers could request viewpoint changes at any moment to inspect details; for instance, when an installation at the entrance obstructed the line of sight, reviewers suggested adjusting its position upwards. VR-based reviews allowed reviewers to feel as though they were physically navigating each design space, resulting in more specific and in-depth feedback. Consequently, students' skills in verbal presentation and spatial demonstration significantly improved.

3.3. Refinement and user testing

After the mid-term review (weeks 8–12), students swiftly refined and validated their designs in VR based on feedback received. For example, an art installation initially obstructing sightlines at the entrance was moved upward by one meter, and lighting was dynamically adjusted to highlight exhibits more effectively. Teachers also introduced a user-testing phase, inviting other students within the university to experience design proposals via VR and provide feedback. Some testers experienced confusion navigating through virtual exhibitions, prompting designers to add clearer wayfinding signage, swiftly addressing the issue. User feedback obtained through VR allowed students to gain initial experience in human-centered iterative design processes.

3.4. Final presentation and insights

At the end of the course (week 16), a virtual exhibition was held to present the design projects. Participants could freely explore each student's design using VR headsets, while walkthrough videos of each proposal were simultaneously displayed on a large screen. The immersive presentation significantly impressed the university audience, who widely agreed that the impact and persuasiveness far exceeded traditional graphic panel displays. This case demonstrated that VR teaching practices markedly enhanced the immersive experience of student projects, the depth of classroom interactions, and students' intuitive judgment of spatial design. Students generally described the course as "more engaging and challenging" and recognized that they had gained essential new skills relevant to their future careers. This case provides valuable insights and practical experiences for the application of VR in environmental design education.

4. Results of teaching reform

The teaching reform conducted in the "Exhibition Space Design" course at the College of Arts, Sichuan University, integrating virtual simulation technology, yielded notable results in the following aspects:

(1) More intuitive and engaging design presentation: Through immersive VR technology, design proposals transitioned from flat drawings into virtual spaces that can be directly experienced. This allowed teachers and students to intuitively grasp the true spatial scale and environmental atmosphere. This direct experiential approach effectively bridged the gap between designers' creativity and audience understanding, making student projects significantly more persuasive and greatly boosting students' confidence and sense of accomplishment in their design presentations.

(2) Significant enhancement in students' interest and design abilities: According to post-course surveys, approximately 65% (32 out of 49 valid respondents) expressed strong interest in VR-supported design teaching, with only one student needing extra time to adapt. Through repeated adjustments and optimization of designs in the virtual environment, students significantly improved their spatial reasoning, as well as their ability to independently identify and solve design problems. The immersive interactivity unique to VR technology effectively stimulated students' creativity and motivation for autonomous learning, enhancing their comprehensive understanding of spatial relationships and optimizing the design process [7,8].

(3) More equal and in-depth teacher-student interactions: The VR environment facilitated multi-

dimensional, real-time interactions and exchanges between teachers and students, transforming the traditional one-way classroom communication model into a more equitable and deeper dialogue. Collaboration and interactions within the VR space became more frequent and proactive, creating a more efficient learning community.

(4) Provision of high-quality, replicable experiences and reference cases: This reform practice not only enhanced the teaching quality of the course itself but also provided high-quality, replicable case experiences for environmental design education. It has the potential to serve as a foundation for future high-level teaching achievements or the development of first-class virtual simulation courses, exerting a broader positive influence.

As shown in **Table 2**, the outcomes achieved by this teaching reform align with the trends and requirements of current higher education development, effectively enhancing the quality of talent cultivation in environmental design courses. By promoting immersive experiential teaching, the course has successfully transitioned from traditional teaching paradigms to a more advanced and innovative virtual experience model. This transition effectively addresses contemporary demands for interdisciplinary training of versatile and innovative talents within the context of the emerging fields of "New Engineering" and "New Liberal Arts."

Table 2. Comparison of teaching effects before and after VR integration

Evaluation dimensions	Traditional teaching	VR-integrated teaching
Design presentation	2D visuals, limited immersion	Virtual space, more intuitive
Student interest	Moderate interest, limited appeal	Significantly increased engagement
Spatial understanding and design skills	Weak spatial sense, slow iteration	First-person perspective, enhanced skills
Teacher-student interaction	One-way, limited interaction	Real-time, deeper interaction
Student feedback	Limited novelty and low challenge	More engaging and challenging

5. Conclusion

While achieving significant educational outcomes, the virtual simulation teaching reform implemented in this study has also revealed several practical challenges and difficulties.

Regarding costs, the purchase and ongoing maintenance of virtual reality equipment pose substantial financial pressures on departmental budgets. This necessitates actively seeking specialized funding and establishing cooperative mechanisms with enterprises to progressively enhance equipment availability and resource utilization efficiency.

Faculty members often lack sufficient experience in applying virtual simulation technology, complicating the smooth implementation of these reforms. To address this, it is essential to implement targeted training programs, foster interdisciplinary teacher collaboration, and appoint technical teaching assistants to alleviate faculty-related issues.

Students have experienced additional burdens when integrating technology into their coursework. To minimize this stress, it is recommended to introduce virtual reality tools gradually and systematically, encourage collaborative group learning opportunities, and carefully plan the duration and complexity of technical training sessions.

Furthermore, virtual classrooms carry certain safety and management risks. Establishing clear usage standards and safety guidelines, strengthening supervision, and upgrading safety facilities are necessary to safeguard teachers and students. Considering the inherent limitations of virtual reality technology, incorporating auxiliary methods such as augmented reality (AR), panoramic displays, or traditional models can enhance teaching flexibility and effectiveness.

Future directions could further broaden the application fields of virtual simulation technology, promote quantitative evaluation research, reinforce interdisciplinary collaboration, and closely track emerging technological trends such as AR and the metaverse. These steps will ensure the ongoing innovation and forward-looking nature of teaching methods.

The experiences accumulated through this reform exploration are highly valuable for optimizing teaching models within the environmental design field. Despite facing multiple challenges, continuous improvements and innovations promise to facilitate the widespread application of virtual simulation technology in daily educational practice, promoting the cultivation of environmental design talent and advancing higher education modernization.

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Disclosure statement

The authors declare no conflict of interest.

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