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On the Application of Digitized Virtual Reality Technology in the Teaching of Landscape Architecture Design

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ABSTRACT

Landscape garden design is an important design foundation course for undergraduate students of landscape architecture in China, but the current classroom teaching has the problem of limited spatial dimension of the course. This paper proposes a virtual scene model construction method through the computer software with the creation of the need to display the scene. This virtual reality technology has immersive, interactive, and risqué characteristics. This paper focuses on the key points of virtual reality technology, discusses the specific implementation method of virtual reality technology in the "landscape garden design" course, and introduces the interactive control principle. The results of the research show that virtual reality technology to assist teaching can cultivate students' spatial thinking and enhance students' spatial simulation experience, greatly reducing the cost of traditional teaching.

KEYWORDS

Computer Science, Intelligent Technology, Landscape Architecture Design, Modelling Analysis, Teaching Link, Virtual Reality Technology

Traditional teaching of landscape design relies mainly on books, floor plans, and hand-drawn models, which cannot allow students to truly experience and feel the spatial sense and atmosphere of the design scheme. Students often struggle to accurately understand and evaluate the effectiveness of design solutions. In addition, traditional landscape design teaching often lacks opportunities for practical application, making it difficult for students to use the knowledge they have learned in real environments. This leads to insufficient cultivation of students' abilities in practice. The emergence of digital virtual reality (VR) technology provides new possibilities and opportunities to solve these problems. Digital VR technology can provide a more realistic, visual, interactive, and efficient learning experience, helping students better understand and apply landscape design knowledge and overcoming some difficulties and limitations in traditional teaching. This article introduces interactive controls based on user gestures and parameter configuration panels based on user gaze and gestures to help researchers better understand digital virtual technology. Meanwhile, through experiments, the superiority and applicability of using VR technology have been confirmed. This article provides

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theoretical and practical references for the improvement and innovation of landscape design teaching, which is conducive to improving the learning effectiveness and design level of students.

LITERATURE REVIEW

The Landscape Architecture Design course is an important basic design course for undergraduates majoring in landscape architecture in my country (Akinci & Akinci, 2018). The teaching goal of the course is to train students to grasp the basic concepts and design thinking of landscape design (Al Ruheili & Al Hajri, 2021). The course is offered from the second semester of the sophomore year to the first semester of the senior year (Brassel et al., 2024). According to the needs of different grades and majors, the teaching and research group arranges one to two design assignments per semester, and each design assignment is completed within eight to ten weeks (Carbonell-Carrera et al., 2020). The teaching content of the Landscape Architecture Design course includes the principles of landscape architecture design, various types of garden green space, and urban public space design (George et al., 2022). Teachers will arrange different design topics to carry out key training for students, such as functional layout, space design, terrain design, plant design, drawing expression, etc. (Hill et al., 2019). Teachers teach theory, task explanation, case analysis, field investigation methods, and design guidance in class (Hsu & Ou,2022). Students design plans during after class and finally make a formal design plan, expressing the design plan in the form of complete drawings (Kerr & Lawson, 2020). Space design is the core content of the Landscape Architecture Design course; it pervades the course, to help students establish a spatial thinking mode, improve space design ability, and train students to master the scale, proportion, atmosphere, layout and design of spatial relationships (Mahrous et al., 2024).

Unlike traditional teaching methods, the teaching of Landscape Architecture Design requires the help of certain media to carry out the communication between teachers and students and the collision of ideas, and finally form the landscape design scheme (Mamajonova et al., 2024). It is understood that the teaching of most Landscape Architecture Design courses at home and abroad relies mainly on the case teaching of teachers, drawing and scrutinizing the design scheme by hand-drawing, hand-modeling, and commenting (Nordh & Evensen, 2022). The teaching of senior grades can be combined with computer-aided design software, such as Auto-CAD, Photoshop, Sketch-up, Lumion, etc., to conduct space design deliberation (Ren et al., 2024). VR technology is a new multi-channel human-computer interaction interface. People use VR helmets and combine with the physical space environment to generate realistic images, sounds and other sensations (Shao et al., 2020). VR simulates user interaction with the environment in a virtual environment (Sleipness & George, 2017). At present, the VR system is mainly composed of a graphics processing computer, an application software system, an input device, and an output device (Staniewska, 2021). VR technology first originated in the United States in the 1960s, and in the 1980s the concept of VR technology was gradually extended to the fields of medical treatment, flight simulation, automobile industrial design, and military training (Wu & Yan, 2021). Since 1990 VR technology has been widely used in business, and with the continuous updating of display equipment products such as VR headsets and simple VR glasses, VR technology has begun to enter the public consciousness and the mainstream of the gaming industry (Wu et al., 2021). At present, major technology companies in our country have project departments dedicated to developing VR products, and VR technology has begun to be used in a wider variety of fields (Zhang & Deng, 2021). VR technology makes the interaction between users and computers more natural; just as with the interaction between humans and nature in reality, users are completely immersed in the virtual environment generated by the computer, giving it the look and feel of an immersive interaction. At the same time, this interaction also allows designers to scrutinize the scheme during the design process and feel the real effect of the design. In addition, the display operation cost of VR technology is relatively low, and it can be operated skillfully after a few minutes of learning. Even if the general public does not have strong professional skills, they can get a clear sense of the real scene of a venue, making it easier for the public to understand the effect of garden design. Thus VR technology has improved the effect of popular science education for the public.

At present VR technology has two common forms of display: one is the real scene obtained by using a panoramic camera to collect information from the actual environment; the other is the virtual scene rendered by computer graphics software. Although the presentation methods of these two technologies are different, they both provide users with an immersive experience. If teachers master these two technology display methods, they can apply VR technology in the teaching of design-related courses. The panoramic data collection of real scenes requires the use of panoramic photography equipment for real scene shooting. At present there are professional independent panoramic cameras on the market, such as Detu F4, Insta360 Pro, GoPro360, etc. There are also portable devices that support mobile phone connection, such as Insta360 one, Ricoh, THETA, etc. The working principle of this type of equipment is to capture data information from different directions through all-glass fisheye lenses and then synthesize panoramic photos or videos through image stitching technology. For example, when collecting the physical space information of landscape architecture, the panoramic photography equipment must first select the sample points of the collection object (Zhang, 2021). The open site is the best collection location, and at the same time, the photographer should avoid tourists as much as possible to ensure that high-quality images are obtained (Zhang & Zhang, 2021). After the data collection is completed, the required panoramic photos or videos are obtained by using the picture stitching technology and then projected to the user's eyes through the VR equipment(Zhao, 2020).

The construction of the virtual scene model requires the use of computer software to create the scene that is to be displayed. For landscape architecture, the scene is an outdoor space composed of landscape architecture elements, including mountains, water features, vegetation, terrain, structures, squares, roads, etc. Commonly used software includes SketchUp sketch master software, Lumion software, etc. The producer first completes the basic model construction of the scene's terrain, roads, bodies of water, squares, structures, etc. using Sketch Up software and then introduces the model into the Lumion software, adjusts materials, adds plants, and establishes background and ambient lighting. Thus a more realistic scene model is obtained. The producer uses the "VR panorama setting" function in the Lumion software to perform VR rendering of the produced scene model. There are currently two formats for producers to choose from. One is the cube panorama format, which renders 12 square images stitched together. Although this kind of picture has high precision, it requires manual picture stitching in the later stage before it can be applied to VR equipment products. In this appliction, teachers can select excellent garden space cases according to the teaching theme, collect VR information, and use 360-degree panoramic cameras to take photos or short videos. Then, the VR model source files and basic information, floor plans, and analysis diagrams are synthesized and edited, and virtual space cases are produced, thereby forming real and three-dimensional garden interactive experience case courseware. When students master the generation skills of the VR panoramic model, they can connect the garden scene they designed with the mobile terminal of the "720 Cloud Platform" to generate the link of panoramic effect and then enter the panoramic experience interface through VR simple glasses, and continue to scrutinize the spatial scale of the design scheme to determine whether it is reasonable and comfortable. If it is unreasonable, students can quickly make adjustments in the model to obtain the most satisfactory garden space design scheme.

RELATED MATERIALS AND METHODS

Teaching Landscape Design

Landscape design teaching refers to the teaching process of cultivating students' theoretical and practical abilities in the fields of landscaping, landscape, and urban design. The main elements of landscape design teaching are as follows:

(1) Teaching content: Landscape design teaching mainly includes the cultivation of knowledge and skills in design principles, landscape planning, plant configuration, material selection, construction technology, and other aspects. Students can master the basic concepts and methods of landscape design through classroom lectures, project design, on-site inspections, and simulation operations.
(2) Teaching methods: Landscape design teaching adopts various teaching methods, including theoretical teaching, case analysis, practical operation, on-site investigation, team cooperation, etc. By combining theory with practice, teachers cultivate students' spatial perception ability, creative expression ability, and design decision-making ability.
(3) Teaching resources: Landscape design teaching requires rich teaching resource support, including library materials, digital image libraries, laboratory equipment, software tools, etc. These resources provide students with reference materials, case studies, and technical support to help them better understand and apply the knowledge they have learned.
(4) Teaching evaluation: The evaluation of landscape design teaching is mainly carried out through assignments, project reports, design works, and oral defense. Students need to demonstrate their achievements in design ideas, scheme expression, technology application, and innovation ability.
(5) Practical opportunities: In order to improve students' practical abilities, landscape design teaching usually arranges practical opportunities such as on-site visits, internships, or participation in real projects. These opportunities enable students to apply the knowledge they have gained to practical projects, cultivating their practical skills and problem-solving abilities.

Overall, landscape design teaching aims to cultivate students' design abilities and innovative thinking, enabling them to become landscape design experts with professional knowledge and practical experience. However, traditional landscape design teaching has always faced some difficulties, and traditional teaching methods often cannot meet the practical needs of students. Before the emergence of digital virtual technology, landscape design teaching faced the following challenges:

(1) Lack of authentic experience: Traditional landscape design teaching relies mainly on books, floor plans, and hand-drawn models for teaching, which cannot allow students to truly experience and feel the spatial sense and atmosphere of the design scheme. Students often struggle to accurately understand and evaluate the effectiveness of design solutions.
(2) Cost and time constraints: Traditional landscape design teaching requires a significant amount of time and cost to construct physical models, conduct on-site inspections, and produce hand drawn drawings. These limitations lead to slow teaching processes and difficulty in meeting the practical needs of students.
(3) Difficulty in showcasing multidimensional effects: With traditional teaching methods, it is difficult to fully showcase the multidimensional effects of garden design schemes, such as material texture, lighting effects, dynamic scenes, etc. Students can only imagine the actual effect of design schemes through two-dimensional drawings and floor plans, which limits their comprehensive understanding and evaluation of the design.
(4) Difficulties in remote cooperation and communication: Traditional teaching methods limit remote cooperation and communication among students. Students often need to engage in face-to-face discussions and evaluations, making it difficult to conveniently share design resources and opinions.
(5) Limited practical opportunities: Traditional landscape design teaching often lacks opportunities for practical application, making it difficult for students to use the knowledge they have learned in real environments. This leads to insufficient cultivation of students' abilities in practice.

The emergence of digital VR technology has largely resolved the teaching difficulties of landscape design. Through digital VR technology, students can immerse themselves in virtual garden spaces, including landscape elements, material textures, lighting effects, etc., thereby enhancing their understanding and perception of design schemes. In addition, digital VR technology can present landscape design schemes in a three-dimensional and multi-dimensional manner, allowing students to more intuitively understand and evaluate the effectiveness of the design. At the same time, students can also modify and optimize the design through interactive operations, view feedback results in real time, and improve the flexibility and creativity of the design. Digital VR technology can save time and physical model resources, and design and demonstration can be carried out through computers or virtual devices, accelerating the design process and reducing costs. Digital VR technology can enable remote collaboration and teaching, allowing students to collaborate on landscape design between different regions, share virtual environments and design resources, and improve the efficiency and convenience of cross-cultural and cross regional communication.

VR Technology

VR technology is a computer technology that simulates real scenes. It uses various sensory input methods, such as computer-generated 3D images and sound, to immerse users in a virtual world, allowing them to interact with the virtual environment as they do with the real world, thus obtaining an immersive feeling. VR technology can be applied in many fields, such as gaming, healthcare, education, entertainment, etc. The process of VR technology generally include the following elements:

(1) Information collection: VR technology requires the collection and integration of a large amount of physical and digital information, such as scenes, models, textures, sounds, etc. This information can be obtained through various means, such as photography, laser scanning, CAD design, etc.
(2) Modeling: Computer software is used to model the scene and create a virtual environment on the basis of the information collected. Modeling can be divided into two aspects: 3D modeling and 2D modeling. 3D modeling converts real objects or scenes into 3D models in the virtual world, while 2D modeling converts real images or graphics into 2D models in the virtual world.
(3) Environmental design: After creating a virtual environment, it is necessary to complete the design of that environment; this step includes art design, lighting design, sound design, etc., which enhance the realism and immersive feeling of the virtual environment.
(4) Programming development: After the environment design is completed, it is necessary to use programming languages to implement VR applications. This process requires the use of professional VR engines and software development tools, including Unity, Unreal Engine, CryEngine, etc.
(5) Testing and optimization: After the development of VR applications is completed, it is necessary to conduct testing and optimization to ensure the stability and performance of the program. Testing can include functional testing, performance testing, and user experience testing.
(6) Release and maintenance: After the VR application passes testing and optimization, it can be released to designated platforms, such as VR helmets, smartphones, etc. Maintenance is the regular updating and fixing of vulnerabilities in VR applications.

VR technology can simulate real environments and provide users with an immersive experience. It can provide a free interactive experience, allowing users to freely explore, operate, otherwise interact with a virtual environment. However, the development and manufacturing costs of VR technology are high, requiring a significant amount of manpower, material resources, and financial investment. In addition, this technology requires supporting equipment to be used, such as VR helmets, which are expensive and not affordable for all users. The operation and maintenance of VR technology is relatively complex, requiring professional technical personnel to maintain and update it.

VR technology brings many new possibilities to the education field, providing more immersive learning experiences, interaction, and cooperation, customized learning, interdisciplinary integration, and opportunities for distance education and cooperation. With the continuous development and popularization of VR technology, we can expect more possibilities for innovation and improvement in the field of education.

(1) Immersive learning experience: VR technology can provide an immersive learning experience, allowing students to personally experience the situation and atmosphere in real scenes. Whether visiting historical sites, exploring natural environments, or participating in practical operations, students can gain a more intuitive and in-depth learning experience through VR technology.
(2) Interaction and collaboration: VR technology can provide an interactive learning environment where students can interact with virtual scenes through gestures, speech, or controllers. In addition, VR can also support multi-person collaboration, allowing students to participate in learning tasks with others, promoting cooperation and the cultivation of team spirit.
(3) Customized learning: VR technology can provide customized learning content and feedback based on the individual needs and learning progress of students. By collecting behavioral data and performance of students in virtual environments, teachers can provide personalized guidance and evaluation based on their learning situation, improving learning outcomes and personal development.
(4) Interdisciplinary integration: VR technology can integrate multiple disciplinary fields and create an interdisciplinary learning environment. For example, when studying science, students can engage in practical operations through virtual laboratories; when studying literature, students can enter the story plot of literary works through virtual scenes. This interdisciplinary integrated learning approach can stimulate students' comprehensive thinking and innovative abilities.
(5) Distance education and remote cooperation: VR technology can break the limitations of time and space, allowing students to engage in remote education and cooperation in different locations. Students can participate in remote courses and collaborate with other students through VR technology to jointly complete project tasks and promote educational exchange and cooperation on a global scale.

The impact of VR on learning and the development of other brain abilities is being widely studied. The main research areas are as follows:

(1) Cognitive ability: VR technology can provide a more immersive learning experience, and by simulating real scenes and situations, it can help improve students' attention, memory, and attention allocation abilities. In addition, VR can also stimulate students' observation, reasoning, and problem-solving abilities, promoting learning at the cognitive level.
(2) Space perception and navigation ability: VR technology can allow students to experience and explore different virtual environments firsthand, helping them establish space perception and navigation abilities. By navigating and locating in a virtual environment, students can improve their sense of direction and spatial awareness in the real world.
(3) Emotional and social skills: VR technology can simulate real emotional and social scenes, enabling students to interact with virtual characters and learn how to communicate and cooperate with others. This kind of emotional and social training helps to improve students' emotional intelligence and social skills and cultivates their communication skills and team spirit.
(4) Creative thinking: VR technology can provide an environment and tools for creative thinking, allowing for artistic creation, design, and simulation experiments in virtual spaces. Through the creative application of VR, students can better unleash their imagination and creativity and cultivate innovative thinking and problem-solving abilities.
(5) Emotional regulation and coping ability: VR technology can simulate various scenarios of emotional stimulation, helping students learn emotional regulation and coping skills. For example, by using VR to simulate situations of fear and anxiety, students can undergo exposure therapy in a safe environment to improve their emotional management and coping abilities.

It should be pointed out that the impact of VR technology on other brain abilities is still being studied, and there are still many unknown areas that need to be further explored. Future research will focus more on the relationship between VR and fields such as learning, cognition, and emotion, in order to better understand its impact mechanisms and potential applications.

VR technology can be applied in many fields, such as gaming, healthcare, education, entertainment, etc. In the field of garden design, VR technology can simulate the effect of garden design by establishing virtual garden models and scenes, allowing users to freely walk, enjoy the scenery, and experience the environment in the virtual environment, thereby better understanding the intention and planning scheme of garden design. At the same time, VR technology can also support landscape designers in producing in interactive design and demonstrations, allowing homeowners to more intuitively and stereoscopically experience the design effect, helping designers better understand homeowner needs and feedback

The application of VR technology in landscape design education is also very extensive. By establishing virtual garden models and scenes, students can be provided with a more intuitive learning experience, allowing them to simulate design and interactive demonstrations in a virtual environment, thereby improving their design ability and creativity.

Interactive Controls Based on User Gestures

Interactive controls based on user gestures are an emerging mode of interaction that allows users to control devices or applications through gestures. This interaction method can provide a more natural, intuitive, and convenient user experience, while also reducing the user's dependence on physical devices. The following are several common interactive controls based on user gestures:

(1) Gesture recognition control: This control can perform corresponding operations such as scaling, rotating, dragging, etc. by recognizing user gestures. Gesture recognition controls usually need to be implemented in conjunction with gesture recognition algorithms.
(2) Touchpad control: This type of control can control devices or applications by sliding, clicking, and other actions of the user's fingers on the touchpad. Touchpad controls are commonly used on devices such as laptops and tablets.
(3) Gesture tracking control: This control can track the movement trajectory of the user's hand and convert it into corresponding commands. Gesture tracking controls typically require the use of devices such as cameras or depth sensors for implementation.
(4) Body tracking control: This control can track the user's body movements, such as head, arm, leg movements, etc., and convert them into corresponding commands. Limb tracking controls typically require the use of devices such as cameras or depth sensors for implementation.
(5) Interactive controls based on user gestures: This can be applied to various scenarios, such as games, smart homes, VR, etc. It allows users to control devices and applications more freely and naturally, thereby improving user satisfaction and experience.

User gesture-based interaction controls include navigation controls, line interaction controls, surface interaction controls, and box interaction controls. Navigation, line, and surface interaction controls are classified as handleless ball-related controls, and the position of the handle ball in such controls will not depend on any of them. The overall change is caused by the change of the handle ball. After the user holds the gesture to update the position of the handle ball, the display state of the control can be updated according to the final position of the handle ball. Its realization method can be expressed as follows:

$$P_i = H \tag{1}$$

If the position of the palm of the user's current frame is set as H, then the updated position P of the handball can be obtained.

The box control is classified as a handle ball-related control. The position of all the handle balls will change because of the user's interaction with a handle ball. The box control is composed as shown in Figure 1. It is composed of display points, whose positions can be expressed as P(i=1…6), C, D, respectively. Let the position of the user's hand in the current frame be H; the position of the center handle ball at the end of the previous frame is C, and the position of the box surface handle ball at the end of the previous frame is Pli (1=1...6); then the control moves. In this mode, the handle ball changes according to the following rules: In the mobile mode, the user changes the position of the box control by moving the center handle ball.

$$C_i = H \tag{2}$$

$$P_i = P_{li} + \left(H - C_l\right) \tag{3}$$

The rules in stretch mode are as follows: the user pulls the box handle ball with a grasping gesture, thereby changing the shape of the entire box interaction control, wherein the stretching of the box handle ball should not destroy the overall shape of the box interaction control and should keep it as a cube. Set the following correspondence R:

$$R = \left\{\left\{P_1, P_2\right\}, \left\{P_3, P_4\right\}, \left\{P_5, P_6\right\}\right\} \tag{4}$$

e.g:

$$R\left(P_1\right) = P_2, R(P_{l1}) = R(P_{l2}) \tag{5}$$

Then Pi can be expressed as:

$$P_i = P_{li} + \frac{\left(P_{li} - R\left(P_{li}\right)\right)\left(H - P_{li}\right)}{\left|P_{li} - R\left(P_{li}\right)\right|\left|H - P_{li}\right|}\left(H - P_{li}\right) \tag{6}$$

At this time, the handle balls except Pi and R(Pi) should be moved to the corresponding position Pj (where j represents the handle balls except Pi and Ri), and the positions of the remaining handle balls in the previous frame are set as Pij, and C can be obtained with Pj:

$$C = \frac{P_i - R\left(P_i\right)}{2} \tag{7}$$

$$P_j = P_{lj} + C - C_l \tag{8}$$

The rotation mode of the box interaction control is determined by the initial position of the user's hand when entering the state relative to the position of the center of the box control. Set the position of the hand in the previous frame as H1 and the center position of the box as C (the position of the center of the box remains unchanged in the rotation mode). The hand position of the current frame is H, the handle ball position is Pli. The rotation axis A and rotation angle θ of the control can be obtained:

$$A = \left(H_l - C\right) \times (H - C) \tag{9}$$

$$\theta = \cos^{-1}\left(\frac{\left(H_l - C\right)(H - C)}{\left|H_l - C\right|\left|H - C\right|}\right) \tag{10}$$

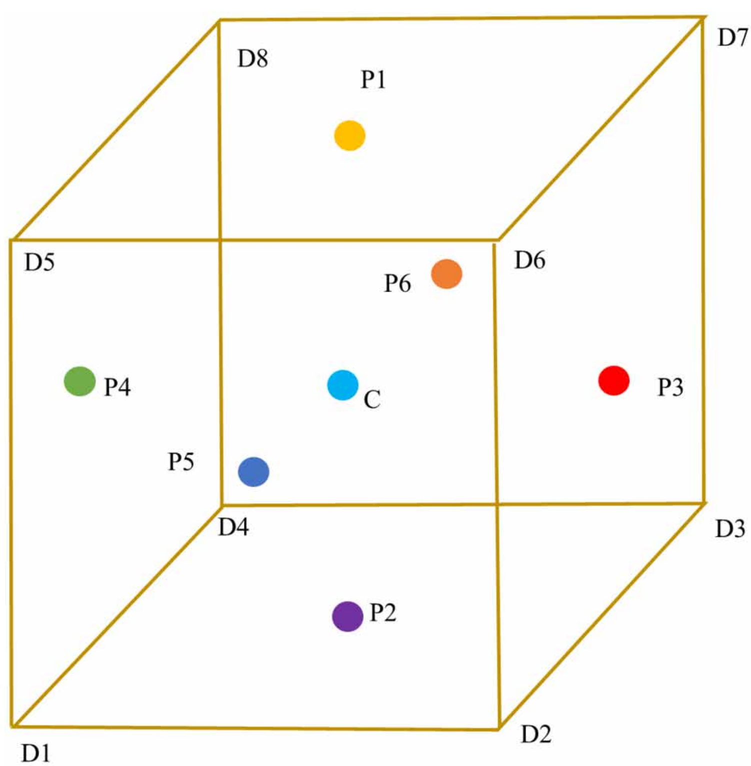
Finally, according to the rotation formula around any axis in three-dimensional space as shown in Figure 1, the rotation matrix M(A, θ) can be obtained from the rotation axis A and the rotation angle θ , and then the coordinates Pi of each handle ball can be obtained:

$$P_i = \mathrm{M}_{(A,\theta)} p_{li} \tag{11}$$

Parameter Configuration Panel Based on User Gaze and Gesture

The parameter configuration panel based on user gaze and gestures is an interactive interface that allows users to modify and configure the parameters of an application or device through gaze and gestures. This interaction method can provide a more natural, intuitive, and convenient user experience while also reducing the user's dependence on physical devices. The following are several common parameter configuration panels based on user gaze and gestures:

Figure 1. Schematic diagram of the implementation of box interactive controls

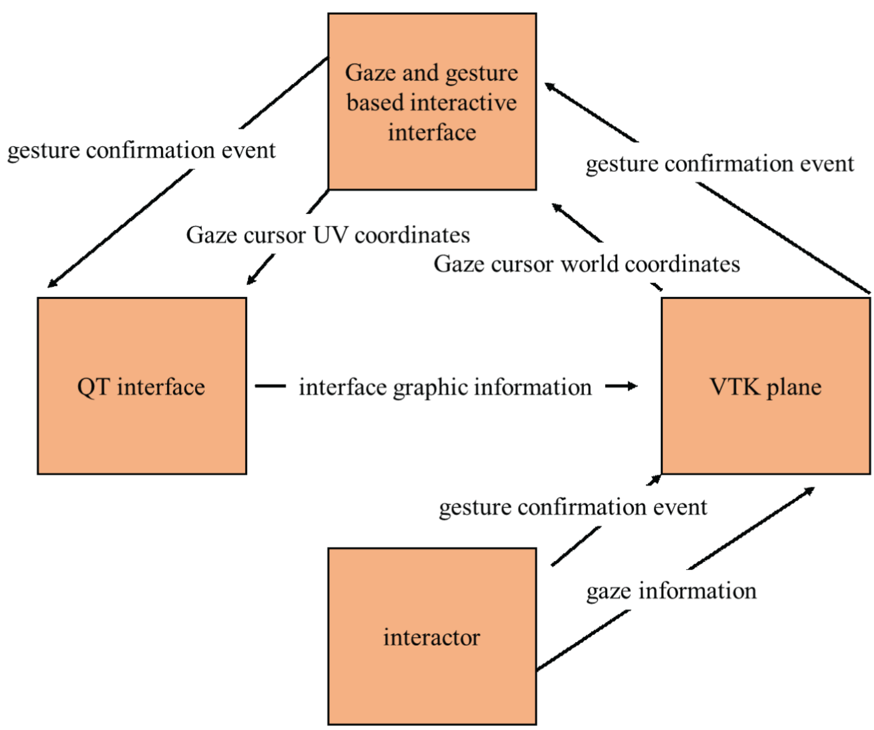


(1) Stare selection control: This type of control allows users to make choices by staring at an option. When a user stares at an option for a certain amount of time, the option will be selected. The gaze selection control usually needs to be implemented in conjunction with eye tracking technology.
(2) Gesture operation control: This control allows users to perform corresponding operations, such as sliding, scaling, rotating, etc., through gestures. Gesture operation controls usually need to be implemented in conjunction with gesture recognition technology.
(3) Parameter adjustment control: This control allows users to adjust application or device parameters, such as volume, brightness, tone, etc., through gestures. Parameter adjustment controls usually need to be implemented in conjunction with gesture recognition technology.
(4) Button control: This type of control allows users to execute corresponding commands such as confirm, cancel, return, etc. by staring at a button. Button controls usually need to be implemented in conjunction with eye tracking technology.

The parameter configuration panel based on user gaze and gestures can be applied to various scenarios, such as VR, smart homes, medical devices, etc. It allows users to control devices and applications more freely and naturally, thereby improving user satisfaction and experience.

In order to meet the parameter configuration requirements of the visualization algorithm, an interactive interface based on user gaze and gestures was developed, and a parameter configuration panel based on user gaze and gestures was implemented in combination with the QT development framework. The working method of the interface is shown in Figure 2. After the interaction panel receives the collision point between the user's gaze vector and the interaction panel, it converts the world coordinate of the collision point into the plane coordinate based on the interaction panel through UV coordinate solution and passes the plane coordinate and gesture confirmation event to the QT interface to trigger QT interface interaction logic.

Figure 2. Working method of interactive interface based on gaze and gesture



The UV coordinate solution method obtained from the HTC Vive Pro device is that the user's gaze emission point is A, its coordinates are (a1, a2, a3), the vector is R, and its value is (r1, r2, r3). Let the origin of the UV coordinates of the interactive panel be O; its world coordinates are (o1, o2, o3). The normal vector of the interactive panel is W, its value is (w 1, w2, w3), and the V-axis vector of the interactive panel is V. Its value is (v1, v2, v3), the U-axis vector of the interactive panel is U, and its value is (u, u2, u3). The available user gaze vector equation is

$$\begin{cases} x = a_1 + r_1 * t \\ y = a_2 + r_2 * t \\ z = a_3 + r_3 * t \end{cases} \tag{12}$$

The interactive panel plane equation is:

$$w_1 * \left(x - o_1\right) + w_2 * \left(y - o_2\right) + w_3 * \left(z - o_3\right) = 0 \tag{13}$$

The immediate variable t can be obtained:

$$t = \frac{\sum_{i=1}^{3} \left(o_i - a_i\right) * w_i}{\sum_{i=1}^{3} w_{i*} r_i} \tag{14}$$

Substituting t into Equation (1), the intersection point B of the user's gaze and the interactive panel can be obtained, and its value is (x, y, z). According to the three-dimensional coordinate system transformation method, the intersection point B is changed from the world coordinate to the coordinate system with U, W, V as the coordinate axes, and the UV coordinate of point B can be obtained, which is expressed as (u, w, v):

$$\begin{pmatrix} u \\ w \\ v \\ 1 \end{pmatrix} = \begin{pmatrix} u_1 & u_2 & u_3 & 0 \\ w_1 & w_2 & w_3 & 0 \\ v_1 & v_2 & v_3 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & -o_1 \\ 0 & 1 & 0 & -o_2 \\ 0 & 0 & 1 & -o_3 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} \tag{15}$$

This section mainly expounds the implementation process of the immersive VR flow field visualization system and the implementation methods of the interactive controls based on user gestures and the interactive panel based on user gaze and gestures.

RESULTS AND ANALYSIS

Analysis of Experimental Results

The research was conducted using a questionnaire survey on "VR use intention and situation" for students and teachers who used VR-assisted design in teaching experiments. The students distributed and recovered 41 valid questionnaires. Correlation analysis did not consider poor students; teachers distributed and recovered 23 valid questionnaires. The results of the questionnaire analysis are as follows:

The collected data are shown in Figures 3 and 4. It can be found that in the multiple-choice question "Reason for using VR," the selection trends of students of different genders were roughly similar. However, boys were shown to be more willing to use VR than girls in the four options of "first-person perspective (real experience)," "understanding space," "thinking ideas," and "convenient communication with teachers and classmates." In the options "VR display effect is good," girls were shown to be more willing to use VR than boys. This is due to the difference in the way of thinking between men and women. Boys are more rational and attach importance to the auxiliary design function of VR; women are more perceptive and attach importance to the visual performance ability of VR.

The selection trend of students with different abilities was also very similar, but there were some subtle differences. First, compared with the excellent and medium groups, the students in the good group were in the "understanding space" and chose the options "easy to communicate with teachers and classmates" and "model available." The percentages of the three items were different; this difference is presumed to be due to the difference in the focus of the students in the good group. They put more emphasis on the design performance function of VR, hoping to improve the drawing efficiency and performance ability. Second, compared with the excellent and good groups, the students in the middle group had a higher proportion of "thinking ideas." It is presumed that the students in the excellent and good groups have good enough thinking ability, while the VR had more effect on the students in the middle group, who have relatively poor thinking ability, due to a strong auxiliary effect.

As shown in Figure 5, teachers and students have the same order of importance at each stage. In order to improve expression, design evaluation, idea creation, and preliminary research, the difference lies in the role of teachers in VR in the other three stages besides the perfect expression stage. There, teachers' recognition is higher than that of students.

As shown in Figure 6, students of different genders ranked the importance of VR in different design stages in the same order. The order from strong to weak is as follows: perfect expression, design evaluation, idea creation, and preliminary research. The difference is that girls had less confidence in the role of VR in the perfect expression stage, but they were more confident than boys in the

Figure 3. The percentage of reasons for using VR among students of different genders

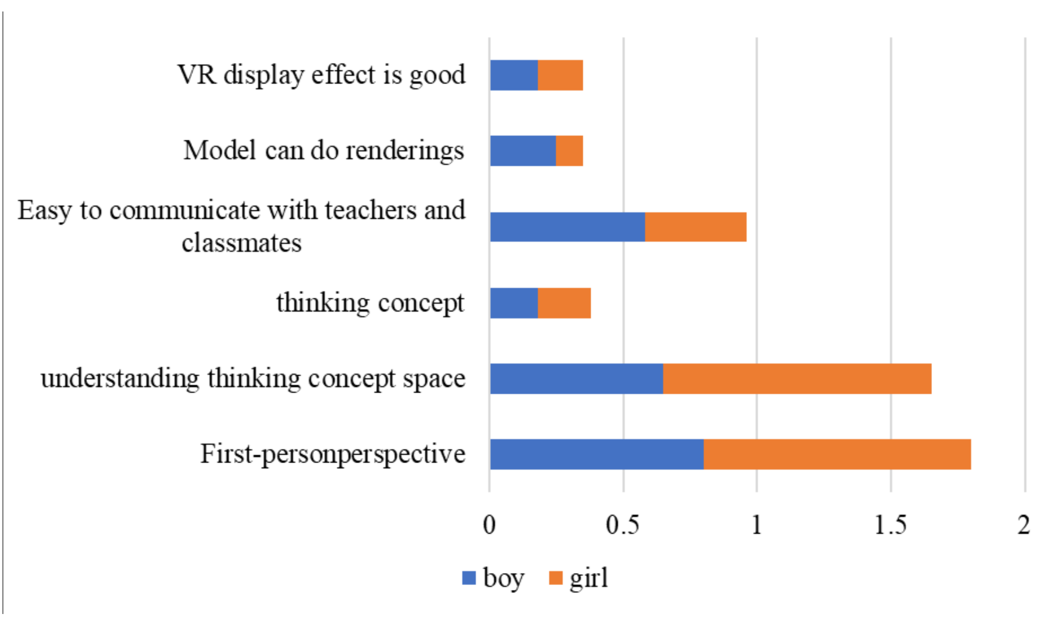


Figure 4. The percentage of reasons for students with different abilities to use VR

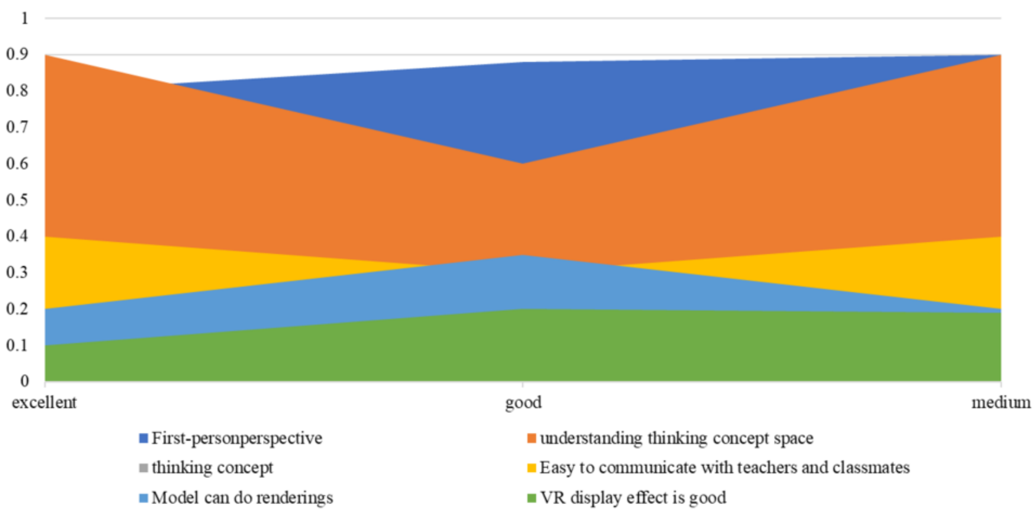
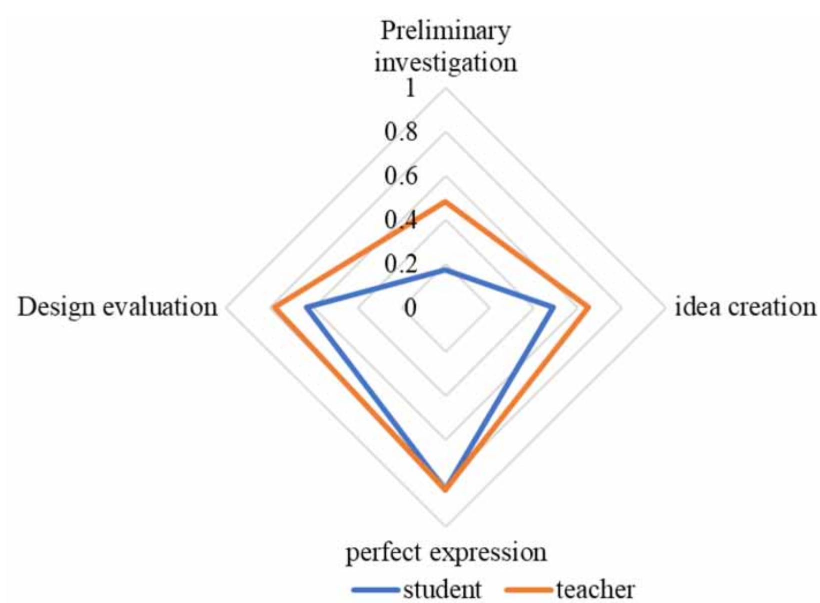


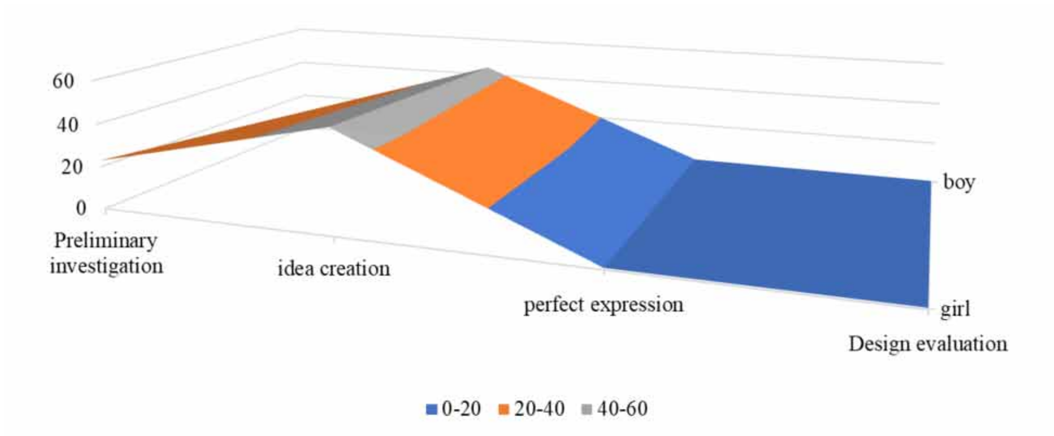
Figure 5. The percentage of teachers and students who think VR is applicable



preliminary research and report and display links. The stage of conception, creation, and perfect expression is more related to rational analysis, which is consistent with men's rational way of thinking; women's perceptual way of thinking pays more attention to visual experience, so the attention of VR in the stage of perfect expression is transferred to the virtual environment that can provide the venue.

As shown in Figure 7, the ranking of the importance of VR in different design stages by students with different abilities was consistent with the gender classification. The difference is that there were large or small differences in the proportions of each stage. It is speculated that learners with different abilities have different emphases on the functions of VR. The students in the excellent group are

Figure 6. Percentage of VR applicable stages for students of different genders

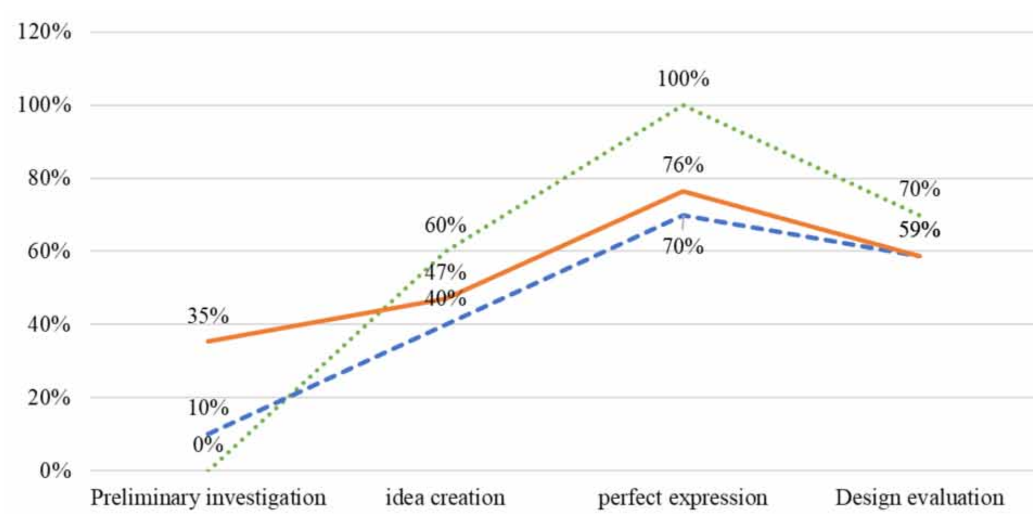


proficient enough in their own abilities and only need the three-dimensional performance ability of VR to assist in the deliberation of space design, so they were higher than other groups in the stage of concept creation and perfect expression. Other stages were equal to or lower than other groups; students in the good group had a higher proportion in the early stage of investigation due to lack of design ideas and the need to conduct relevant research through VR; students in the middle group pay more attention to design performance, so they had a higher proportion in the presentation stage.

This section draws the following two conclusions through the teaching experiments and questionnaire surveys:

(1) Through teaching experiments and data analysis, it is proved that VR does have an impact on architectural design teaching, and the impact on students of different genders and abilities is different.

Figure 7. The percentage of VR applicable stages for students with different abilities



The experimental results show that VR has a positive effect on women but no significant effect on men; it has a significant effect on the students in the good group and the middle group, but the positive and negative effects coexist. Different types of learners have subtle differences in the selection of questions in questionnaires, but there are also commonalities. In the "reasons for using VR" question, everyone believed that "first-person perspective (real experience)," "understanding space," and "convenient communication with teachers and classmates" were the main reasons for use; in the "VR application stage" question, they all believed that the order of importance of VR application stages from large to small is perfect expression, report display, idea creation and preliminary research.

(2) Comparing the results of the teaching experiment and the questionnaire survey, it is found that the reason VR has both positive and negative effects on the students may be the differences in the students' own attention to VR.

The teaching experiment data shows that VR had a significant impact on the students of the good and middle groups, but it had both positive and negative effects, and it had a positive impact on students with other ability levels. The choice tendency of this group in that question was also often different from that of students with other abilities. It is speculated that the negative impact of VR on these two types of students was caused by the difference in the students' focus. VR may have a positive impact on learners; when there is a significant difference between the focus of students of a certain ability level and the focus of students of other abilities, VR may have a negative impact.

Analysis of Practical Applications

According to the above data and conclusions, the research can provide support for the following determination of the impact path of VR and the comparative analysis of VR teaching and traditional teaching.

Although this paper has made some progress in studying the issues and challenges of landscape design teaching, there are still some limitations that need to be noted. In the process of resolving the difficulties in landscape design teaching, we must recognize the following limitations: limited data sources, limited research perspectives, insufficient research samples, and the replicability of practical operations. To address these limitations, we need to adopt corresponding strategies to improve the accuracy and applicability of our research.

(1) Limited data sources: This paper mainly adopts the methods of literature review and case analysis to explore the problems and challenges of landscape design teaching. Although these methods can provide rich information and cases, the insufficiency of data sources may be a problem. In addition to literature review and case analysis, more data and information can also be collected through methods such as questionnaire surveys and field interviews. This can increase the credibility and practicality of the research.
(2) Limited research perspective: This paper mainly explores the problems and challenges faced by landscape design teaching from a teaching perspective and proposes corresponding solutions. However, this paper does not address the impact of other factors on landscape design teaching, such as policy and market demand. Therefore, the conclusions of this paper have certain limitations. In the process of research, different influencing factors should be considered, such as policies, market demand, etc., in order to comprehensively and deeply explore the problems and challenges faced by landscape design teaching.
(3) Insufficient research sample: This paper has selected some cases for analysis and summary, but the sample size is limited and may not fully represent the overall situation of landscape design teaching. Therefore, the universality of the conclusion still needs further verification.

By expanding the scope of case selection and increasing the number of survey subjects, the number of research samples can be increased to improve the universality and reliability of research conclusions.

(4) Limited replicability: This paper proposes some solutions, such as using VR technology to simulate design effects, establishing online platforms to support remote cooperation, etc. However, the implementation of these plans requires certain technical support and resource investment, making these solutions difficult to quickly replicate in all teaching scenarios since they require implementation based on specific circumstances. In response to the problems and challenges faced by landscape design teaching, it is necessary to constantly seek innovative solutions. For example, using artificial intelligence technology to assist landscape design and establishing online platforms to promote remote cooperation can improve the efficiency and quality of landscape design teaching.

In summary, measures such as expanding data sources, conducting multi-perspective research, increasing research samples, and seeking innovative solutions can effectively address the limitations of this paper and improve the credibility and practicality of research conclusions. The research significance of this paper is reflected mainly in the following aspects:

(1) Expanding teaching methods for landscape design: Digital VR technology provides a new teaching method and means for landscape design teaching. By conducting in-depth research and applying this technology, traditional teaching paradigms can be expanded, providing more intuitive, authentic, and interactive learning experiences, thereby improving student learning outcomes and interests.
(2) Enhancing students' design abilities: Digital VR technology can help students better understand and evaluate design solutions and cultivate their spatial perception ability, creative expression ability, and design decision making ability. Through practical operations and feedback mechanisms, students can continuously optimize and improve their designs, enhancing their overall design abilities.
(3) Addressing the challenges in traditional teaching: Digital VR technology can address some of the challenges in traditional landscape design teaching, such as lack of authentic experience, cost and time constraints, and difficulty in showcasing multidimensional effects. By applying this technology, a more realistic, visual, interactive, and efficient learning experience can be provided, making up for the shortcomings of traditional teaching.
(4) Promoting cross-regional cooperation and remote teaching: Digital VR technology can promote cross-regional cooperation and remote teaching in landscape design teaching. Students can collaborate in virtual environments between different regions, share design resources and opinions, and broaden their horizons and communication scope.
(5) Promoting the integration of landscape design teaching and practice: Digital VR technology provides a good opportunity for the integration of landscape design teaching and practice. Students can engage in practical operations and demonstrations in a virtual environment, better apply their knowledge, and improve their problem solving and innovative design abilities.

In summary, the research significance of this paper lies in exploring the application of digital VR technology in landscape design teaching, providing theoretical and practical references for improvement and innovation in landscape design teaching, and enhancing the learning effectiveness and design level of students. In addition, the suggestions for future landscape design teaching in this article are as follows:

(1) Strengthen the application of VR technology in landscape design. With the continuous development of VR technology, more teaching tools and application scenarios based on VR technology can be explored to further improve students' learning experience and design abilities.
(2) Promote online platforms and explore more remote collaboration models. The establishment of online platforms can provide more convenient and flexible working methods for landscape designers and students, further explore and promote remote collaboration models, and enable students and teachers to participate in landscape design projects together in different locations.
(3) Establish a more comprehensive practical teaching system. Landscape design education needs to focus on the cultivation of practical elements, which can further strengthen cooperation with enterprises and society, establish a more comprehensive practical teaching system, and provide students with more authentic and practical opportunities.
(4) Develop intelligent landscape design and management technology. With the rapid development of the Internet of Things, big data, and artificial intelligence technology, more intelligent technology-based garden design and management methods can be explored to achieve refined, intelligent, and sustainable garden construction and management.

In short, there are still great challenges and development space in the field of landscape design education and practice in the future, and continuous exploration and innovation are needed to meet the society's demand for high-quality landscape design talents.

CONCLUSION

This article points out the problems and limitations of traditional landscape design teaching through analysis. Traditional teaching relies mainly on books, floor plans, and hand-drawn models, which cannot allow students to truly experience and feel the spatial sense and atmosphere of design schemes; traditional teaching also lacks practical opportunities, resulting in insufficient cultivation of students' abilities in practice. Therefore, digital VR technology has emerged, providing new possibilities and opportunities to solve these problems. This article introduces the application of interactive controls based on user gestures and parameter configuration panels based on user gaze and gestures to help researchers better understand digital virtual technology. At the same time, the superiority and applicability of VR technology have been confirmed through experiments, providing theoretical and practical references, which are conducive to improving students' learning effectiveness and design level. However, this article must also acknowledge that VR technology still has some limitations. For example, the current cost of VR technology is relatively high, requiring a large number of hardware and software supports, making its popularity in teaching relatively low. In addition, the application of VR technology also requires more practical verification and improvement to achieve more realistic, visual, and interactive effects. In the future, we can continue to study the application of digital VR technology in landscape design education and explore how to combine it with other teaching methods to form a more complete and effective teaching mode. Meanwhile, in the development of VR technology, attention can also be paid to improving its popularity and user experience to meet the needs of more students and teachers.

DATA AVAILABILITY

The figures used to support the findings of this study are included in the article.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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REFERENCES

Akinci, A., & Akinci, Y. C. (2018). Virtual reality (VR) as innovative technology in landscape architecture education. In Educational sciences research in the globalizing world (pp. 11-18). St. Kliment Ohridski University Press.

Al Ruheili, A., & Al Hajri, S. (2021). The role of 3D printing technology in landscape architecture teaching and learning practices. *Educational Sciences: Theory & Practice, 21*(2), 13 - 26.

Brassel, S., Brunner, M., Campbell, A., Power, E., & Togher, L. (2024). \Exploring discussions about virtual reality on Twitter to inform brain injury rehabilitation: Content and network analysis. *Journal of Medical Internet Research*, *26*(1), e45168. doi:10.2196/45168 PMID:38241072

Carbonell-Carrera, C., Saorin, J. L., & Hess-Medler, S. (2020). Spatial orientation skill for landscape architecture education and professional practice. *Land (Basel)*, *9*(05), 161. doi:10.3390/land9050161

George, B. H., Fernandez, J., & Summerlin, P. (2022). The impact of virtual reality on student design decisions: Assessing density and proximity when designing in virtual reality versus traditional analog processes. *Landscape Journal, 41*(1), 31-44.

Hill, D., George, B. H., & Evans, D. (2019). How virtual reality impacts the landscape architecture design process at the site-scale during the phases of analysis and concept development. *Landscape Research Record, 8*, 48-60.

Hsu, C. Y., & Ou, S. J. (2022). Innovative practice of sustainable landscape architecture education—Parametric-aided design and application. *Sustainability (Basel)*, *14*(8), 4627. doi:10.3390/su14084627

Kerr, J., & Lawson, G. (2020). Augmented reality in design education: Landscape architecture studies as AR experience. *International Journal of Art & Design Education, 39*(1), 6-21.

Mahrous, A., Dewidar, K., Refaat, M., & Nessim, A. (2024). The impact of biophilic attributes on university students level of satisfaction: Using virtual reality simulation. *Ain Shams Engineering Journal*, *15*(1), 102304. doi:10.1016/j.asej.2023.102304

Mamajonova, N., Oydin, M., Usmonali, T., Olimjon, A., Madina, A., & Marg'uba, M. (2024). Parametric design: Enhancing architectural environments through computational innovation. *Holders of Reason, 2*(1), 334-345.

Nordh, H., & Evensen, K. H. (2022). Landscape architecture design and well-being—Research challenges and opportunities. *Sustainability (Basel)*, *14*(8), 4522. doi:10.3390/su14084522

Ren, H., Zheng, Z., Zhang, J., Wang, Q., & Wang, Y. (2024). Electroencephalography (EEG)-based comfort evaluation of free-form and regular-form landscapes in virtual reality. *Applied Sciences (Basel, Switzerland)*, *14*(2), 933. doi:10.3390/app14020933

Shao, J., Bai, H., Shu, S., & Joppe, M. (2020). Planners' perception of using virtual reality technology in tourism planning. *Ereview of Tourism Research*, *17*(5).

Sleipness, O. R., & George, B. H. (2017). Impacts of immersive virtual reality on three-dimensional design processes: Opportunities and constraints for landscape architecture studio pedagogy. *Landscape Research Record, 6*(1), 2-11.

Staniewska, A. (2021). Activity and inclusion—The need for enhancing the curriculum on universal design for landscape architecture. *World Transactions on Engineering and Technology Educatio*n, *19*(1), 125-30.

Wu, H., & Yan, J. (2021). The mechanism of digitized landscape architecture design under edge computing. *PLoS One*, *16*(9), e0252087. doi:10.1371/journal.pone.0252087 PMID:34555046

Wu, W. L., Hsu, Y., Yang, Q. F., & Chen, J. J. (2021). A spherical video-based immersive virtual reality learning system to support landscape architecture students' learning performance during the COVID-19 era. *Land (Basel)*, *10*(6), 561. doi:10.3390/land10060561

Zhang, M., & Deng, X. (2021). Color effect of landscape architecture design under computer aided collaborative design system. *Computer-Aided Design and Applications, 19*(S3), 13-22.

Zhang, T. (2021). Research on environmental landscape design based on virtual reality technology and deep learning. *Microprocessors and Microsystems*, *81*, 103796. doi:10.1016/j.micpro.2020.103796

Zhang, X., & Zhang, D. (2021). Teaching of remote sensing technology for landscape architecture in the context of spatial information technology. *International Journal of Emerging Technologies in Learning*, *16*(15), 125. doi:10.3991/ijet.v16i15.24885

Zhao, X. (2020). Application of 3D CAD in landscape architecture design and optimization of hierarchical details. *Computer-Aided Design and Applications, 18*(S1), 120-132.