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Effects of Multisensory Integration through Spherical Video-Based Immersive Virtual Reality on Students' Learning Performances in a Landscape Architecture Conservation Course

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Abstract: Many courses are transitioning from offline to online instruction in the wake of the COVID-19 pandemic. Landscape architecture conservation courses face problems such as reduced interest in learning, poor learning attitudes and low learning efficiency among students. At the same time, due to the nature of landscape architecture conservation courses, students need more experience to learn well, and many landscape architecture courses do not meet this requirement. Online education also lacks the necessary education scenarios and is not very immersive, making it difficult to meet students' learning needs. Continued advances in technology have provided new ways for people to connect with nature, increasing awareness and adoption of sustainable landscape architecture practices. To solve the above problems, this study uses multisensory spherical video-based immersive virtual reality technology to develop a VR learning system for landscape architecture conservation courses based on the senses of sight, sound and smell. This system is simple to operate, but interactive and immersive. A quasi-experimental study was also conducted to test the effectiveness of the system. Analyzing the results of the study, students in the experimental group outperformed students in the control group in terms of learning achievements, learning model satisfaction, technology acceptance, flow experience and learning attitudes, which suggests that the use of multisensory spherical video-based immersive virtual reality technology in a landscape architecture conservation course is effective in improving students' learning performances, and that the study can provide input for the development of other courses.

Keywords: virtual reality technology; landscape architecture conservation course; learning performance; learning attitude; teaching effects

Citation: Wu, W.; Zhao, Z.; Du, A.; Lin, J. Effects of Multisensory Integration through Spherical Video-Based Immersive Virtual Reality on Students' Learning Performances in a Landscape Architecture Conservation Course. *Sustainability* **2022**, *14*, 16891. https://doi.org/10.3390/su142416891

Academic Editors: Ebru Ersoy Tonyaloğlu, Birsen Kesgin Atak, Melih Bozkurt and Hanife Vardı Topal

Received: 23 November 2022
Accepted: 12 December 2022
Published: 16 December 2022

1. Introduction

In today's situation of rapid global economic development and urban construction, the expansion of urban development through the excavation of mountains and roads and the need to construct buildings on flat surfaces inevitably results in the destruction of natural landscapes and environments [1]. With the improvement of living conditions, people's awareness of environmental protection has been decreasing drastically. Domestic waste and garbage have brought harm to the natural landscape [2], and in some places, natural landscape resources have been more seriously damaged [3]. Natural landscape resources include four categories: sky view, land view, water view and life view, which have aesthetic characteristics of morphological beauty, color beauty and symbolic beauties [4] Along with the increasing spiritual needs of human beings, people are paying more and more attention to natural landscape resources and their awareness of natural landscape protection is gradually increasing. The sustainable development and conservation of natural landscape resources is also becoming an important research topic. The dissemination and practice of green sustainable development concepts is becoming an important part of the landscape conservation curriculum. Many schools in China and overseas offer courses on landscape planning and conservation for students to improve their awareness and capability of natural landscape conservation with professional knowledge and skills. However, the formation of habits and the development of awareness need to undergo a long period of accumulation, and for students who have not yet entered the society, it is necessary to educate them about the conservation of natural landscapes. As a result, several schools have also started to offer courses on nature and landscape conservation to create awareness of landscape conservation and develop proper behavioral habits for students [5].

With the COVID-19 pandemic raging around the world, the education industry is facing unprecedented impacts. Students are unable to enter classrooms, and many schools have called for "stopping school, not stopping studying". They have adopted an online-based teaching model, and online education has become the primary means of teaching during the pandemic. In the post-pandemic era, online education will still continue to play an important role [6]. It played an important role in the epidemic period, but for some majors with strong hands-on needs, such as art practice courses, which require students to visit museums and develop artistic sensitivity in the process of visiting artworks, online education has not played an effective role. The best way to educate students for them to visit and feel untouched landscapes and destroyed landscapes, which can make them realize the consequences of the destruction of landscape architecture. If the knowledge is only taught by teachers with pictures or videos online, it is not possible to achieve the educational requirements when teachers lack certain educational experience [7]. Moreover, it is difficult for students to have the feeling of being in the scene, and they can hardly realize the seriousness of the destruction of the landscape, making it difficult to cultivate students' awareness of landscape conservation.

The rapid development of virtual reality technology has proven to be usable and important in several fields. Virtual technology is based on the principle of using electronic technology to immerse an individual in a computer-simulated environment. It is a tool that provides greater participation and autonomy for users in academic research or in purposeful activities by providing an immersive, interactive and shared experience for the user [8]. The role of virtual display technology in student education has gradually emerged and is having a greater impact on classroom teaching. It can promote more immersive engagement in environments that are not normally accessible to students, and it allows a better sense of immersion, with 3D models and interactive videos that give a sense of reality to the computer-generated virtual scenes [9]. Combining virtual reality technology with online teaching can effectively solve the problems that exist in ordinary online teaching.

In addition, there are some problems with landscape architecture conservation courses. The traditional teaching model, which leads students to visit the destroyed or un-preserved landscape architecture, requires significant time and money, in addition to the fact that some of the destroyed landscapes will have pollutants, etc., which can cause certain hazards to the students' health. There are also some landscapes that are geographically inaccessible or difficult to reach, and the safety of students cannot be guaranteed. Therefore, the use of virtual reality technology in landscape architecture conservation courses is necessary [10]. Many researchers and schools have found that the use of virtual reality technology suffers from high costs and difficulties in implementation, as well as difficulties for teachers in designing instructional materials. As a result, more and more interactive surround-image virtual reality systems/resources are being developed today [11].

The spherical video-based immersive virtual reality technology (hereafter referred to as SV-IVR, a viewable VR based on 360° panoramic video or images) used in this article is one such form of VR that can meet the needs of the school environment. It is cheaper than traditional VR and easier to operate, and for the production of material, only requires the use of a panoramic camera, such as Insta360. The general public can now create their own 360-degree spherical images or video footage quickly and easily. Therefore, it is relatively simple and convenient for teachers to create VR materials through SV-IVR, which is easy to promote. At the same time, SV-IVR can not only provide a realistic virtual reality environment, but also provides better interactivity with the experience [12]. The innovation of this article is that we add elements related to smell and hearing to the SV-IVR system. For example, when students feel the deforestation and pollution of rivers through SV-IVR, teachers can control electronic components to release a harmless synthetic smell and play pre-recorded sounds of birds chirping in the forest, the sound of felling trees, etc. This can make students more immersed. Through their sensory perception, they will become more aware of the importance of nature conservation, eventually achieving the goal of developing students' environmental awareness. As Chien, S.-Y., Hwang, G.-J., & Jong, M.S.-Y.E. [13] and Huang, H.L., Hwang, G.J. and Chang, C.Y. [14] have pointed out, there are still some problems in the application of this field of study. For example, there is a mismatch between the cost of technology and the actual situation, the immersion is not strong, operation is difficult and it is difficult for teachers to start. However, the SV-IVR system we use can effectively solve these problems, reduce the cost and operational difficulty, improve the immersiveness of the learning system, and better integrate virtual reality with classroom education.

This study develops a landscape architecture conservation multisensory SV-IVR learning system to address the problems that exist in current landscape architecture conservation courses. The innovative addition of auditory and olfactory elements to the learning system forms a multisensory experience learning system, creating a new learning style and learning experience. A variety of sensory experiences are integrated into the learning system, making the learning system more immersive through visual, olfactory, auditory, tactile and other intuitive senses, which can effectively solve problems such as low student learning efficiency, single teaching path, insignificant teaching effect and high technical cost in current landscape architecture conservation courses [6]. This study used a quasi-experimental study to compare and analyze the effects of the learning model using a multisensory SV-IVR learning system and the traditional teaching model in a landscape architecture course, and analyzed whether the multisensory SV-IVR learning system based on the landscape architecture conservation course improved students' learning performance, enhanced students' learning model satisfaction, improved students' technology acceptance, enhanced students' flow experience and improved learning attitudes. The expected results of this study are positive.

2. Literature Review

2.1. Virtual Reality Technology

According to the scholars Burdea and Coiffet, virtual reality technology has three main characteristics, namely immersion, interaction and imagination [15] According to research reports and literature, virtual reality technology in education differs from traditional 3D technology. It can provide immersive learning environments and experiences. With rapid development, communication technology and multimedia technology are being widely used. The digital information processing cannot meet the actual needs of people and deviates from the way people know the world. People are adept at using touch, sight, hearing and limbs to perceive and engage in information processing [16]. With the development of information technology, artificial intelligence, image processing technology and simulation, sensing virtual reality technology is playing an increasingly important role in people's work and learning [17]. The ideal virtual reality technology is one that creates an audio-visual realistic virtual environment via a computer. Users can enter this environment and can not only immerse themselves in the virtual environment, but also query, analyze, evaluate, plan and make decisions. The ideal virtual reality technology also provides users with means of intuitive and natural real-time perception and interaction such as vision, hearing, touch, smell and taste. It maximizes the convenience of human–computer interaction and makes the whole system more efficient, rather than requiring monotonous and tedious typing [18].

The integration of multisensory experiences in our SV-IVR learning system will enhance the immersion experience for students, as in Richard E's study, in which he mentioned that haptics involving physical interaction with virtual environments can be combined with other sensory modalities such as vision and hearing, but are rarely associated with other feedback channels such as olfactory feedback [19]. In the SV-IVR learning system, we added olfactory experiences; students can feel the uniqueness of real scenes through olfactory experiences such as smelling the trees of the rainforest and the stench of a polluted river. As Ghinea G mentioned in his study, olfaction is one of the last challenges that must be overcome in multimedia and multimodal applications. Enhancing such applications with olfactory stimuli has the potential to create more complex and richer user multimedia experiences through an enhanced sense of reality and diverse user interactions [20]. Olfactory enhancement in multimedia is used for a variety of purposes, including notification alerts, which enhance the sense of realism and presence in immersive applications. Therefore, in this study, we combined olfaction with other sensory systems and focused on the perceptual experience given to students by the virtual reality system, with the aim of discovering important quality assessment factors for these applications from the perspective of landscape architecture conservation courses. We attempted to give students a more novel learning experience with a more comprehensive simulated sensory system, thus ensuring the continued development and success of the landscape architecture conservation course SV-IVR learning system.

Hearing is also an important sense, and an experiment at the Virtual Reality Lab at Oldenburg University showed similarities and differences in the behavior and performance of laboratory and field subjects. This suggests that the current state of the virtual reality laboratory marks a step toward greater ecological validity in laboratory-based hearing and listening device research, but further development toward greater levels of ecological validity is needed [21]. In the virtual reality environment of this study, we designed corresponding learning tasks based on existing experience and knowledge of landscape architecture conservation courses through the interplay of smell and hearing. Learners can intuitively accumulate and complete knowledge construction and increase their learning autonomy. In this environment, each learner is an individual that is fully immersed in the virtual environment. It is an experience that learners cannot feel in the real world, and it can greatly stimulate learners' enthusiasm for learning, enrich abstract or tedious theoretical knowledge and provide then with learning experiences. Han PH's team introduced a hybrid haptic feedback system that uses fans, hot fans, mist generators and a heat light to reproduce multiple haptic sensations in virtual reality as a way to enhance immersive environments and improve interactivity. As users move through the virtual space and interact with virtual objects, they can perceive sight, sound and touch [22]. In our study, which also demonstrated the potential of a mixed-sensory system in a landscape architecture conservation course with virtual reality technology, students rated enjoyment, realism, quality and immersion higher. The VR teaching model reduces unnecessary travel and carbon emissions in a greener and more sustainable way while adding to the immersion and experience of the landscape architecture conservation course. At the same time, the VR course itself is a sustainable and valuable teaching resource as a knowledge carrier that can be reused for sustainable learning.

2.2. Landscape Architecture Conservation Course

Landscapes are a special resource. People, on the basis of nature, through imagination, processing, modification and other acts, give landscapes the idea of beauty and cultural connotations, so that they are permeated with human civilization and the cohesion of human spirit and thought. Scenery is the objective factor and basic material of landscapes; it is the individual material with independent appreciation value. Sense of scenery is the active factor of landscape composition and subjective response; it is the human observation, identification and feeling ability of the landscape. Through protection and cultivation, development and utilization, and management and administration, landscapes can play a variety of functional roles and promote the healthy development of integrated arrangements as well. The characteristics of landscape architecture conservation courses determine the attributes of multidisciplinary cross-fertilization, multi-system coupling and multi-level penetration linkage. Therefore, landscape architecture conservation courses should also be based on basic attributes and establish a broad, open and integrated system architecture. The application of the SV-IVR learning system in landscape architecture conservation courses is based on the properties of the course itself. Through an all-round immersive experience of sight, sound, touch, smell and taste, it better establishes and cultivates students' thinking ability for landscape architecture conservation, and can eventually meet the targeted teaching goal of the course [23].

Nature, as an entity, is the living environment of people and the location of people's lives. Therefore, landscape architecture conservation education requires schools to provide students with comprehensive knowledge of humans and society, atmosphere, soil, water, solid waste, ecological environments, etc., so that students can fully understand the impact of human development and natural changes on the environment, and enhance contemporary landscape architecture conservation education. Landscape architecture conservation courses can effectively enrich the content of environmental and conservation education by using environmental issues in students' lives as educational content and enhancing the realism of landscape conservation education. A study by Heba Adel Ahmed Hussein from the Faculty of Engineering, University of Port Said, Egypt explored the benefits and potential applications of integrating augmented reality (AR) technology into landscape design education to create a more beneficial educational environment, provide a fun learning atmosphere and deepen students' understanding of the landscape design process. The study found that the integration of AR with traditional teaching methods was useful and positively impacted the landscape architecture conservation course [24]. Zhe Li from the School of Architecture, Southeast University of China, discussed the application of computer virtual reality technology in landscape teaching in order to improve the digital level of landscape design. Using SketchUp virtual modeling software to illustrate and demonstrate specific cases, the application results show that the introduction of computer virtual technology in the teaching of landscape design in colleges and universities can effectively improve teaching efficiency, SketchUp modeling can also complete the virtual modeling of buildings, vegetation, etc., to assist in landscape design. Therefore, Zhe Li believes that the application of virtual reality technology in landscape design teaching is of great significance [18].

With the rapid development of digital VR technology, teachers can use this technology to simulate real-life scenarios and give students access to them. The University of Florida's Agriculture and Natural Resources Communication program used 360-degree cameras, mobile devices and online software to create a virtual reality tour of a forest, focusing on forest conservation, climate change education and the impact of the tour on the public. The results showed that the students improved their multimedia communication skills, knowledge of natural resource conservation and confidence in communicating with the public [25]. Jian Huang constructed a snow and ice landscape resource by using software optimization for variable teaching of snow and ice landscape forms. The snow and ice scenes use the appropriate equipment to enhance their perceptual landscape [26]. Studies have shown that this has a positive effect on improving students' aesthetic appreciation. ShaojingFan analyzed the potential value of virtual reality technology in environmental education and proposed a metaphor-based generic architecture for virtual reality systems as an environmental learning tool. Statistics showed that the application of virtual reality technology in environmental education not only can improve the quality of education, but also can solve some problems in environmental experiments [27]. The use of landscape conservation courses is not limited to the classroom; they can play a role in preserving cultural heritage and geomorphic features. The Spanish team of Antonio Monterroso-Checa created a virtual lookout (GuadiatVR) for a rural cultural heritage site in Córdoba [28]. In a study on students' perceptions and learning experiences of online education during the COVID-19 outbreak, Tugba Duzenli's team from Turkey noted that the online platforms used in distance education greatly affected students' perceptions and learning [29].

In addition, researchers have encountered a number of problems, particularly focusing on the ways in which virtual reality technology can empower curriculum education and how to enhance students' classroom immersion, classroom motivation and interest in learning. They have emphasized that in the education and teaching of landscape architecture conservation courses, online learning combined with digital technology needs to be further developed and improved. However, the current research is more at the grassroots technical level of virtual reality, and is lacking certain technical and innovative solutions. Therefore, through the analysis of VR technology and landscape architecture conservation courses, we find that most of the above studies are still at the stage of theoretical research and preliminary testing; they have not yet formed a virtual education system. There is still the problem of imperfect transformation of landscape architecture conservation knowledge courses. In fact, the practical application of virtual reality technology in the teaching of landscape architecture conservation courses has not yet been realized. In contrast, the SV-IVR learning system has been implemented in natural landscape architecture conservation courses for course design and course application. It has received real experimental results and valid data feedback from teachers and students. In the multisensory SV-IVR learning system, we are able to add visual, auditory, tactile, olfactory, gustatory and other intuitive and natural means of real-time perception and interaction to distance education, which provides better timeliness and immersion, with greater interaction and communication between voice and senses. The SV-IVR learning system, empowered by the internet and technology, enables students to experience immersive natural landscape scenes without having to leave home, better promoting the practice and dissemination of green and sustainable concepts. The multisensory SV-IVR learning system can achieve more significant learning effects in a more innovative way; at the same time, it can enhance students' motivation and knowledge of landscape architecture conservation. There is a lack of research on the use of the SV-IVR learning system in landscape architecture conservation courses, making this an innovation of the SV-IVR learning system and landscape architecture conservation course teaching.

3. Materials and Methods

A quasi-experimental study was conducted to investigate whether the multisensory SV-IVR learning system could improve the teaching effectiveness of landscape architecture conservation courses. Quasi-experimental design is a research method that applies the methods of real experiments to solve practical problems. It is implemented under conditions close to reality, applying the principles and requirements of real experimental design as much as possible, controlling factors to the maximum extent possible and conducting experimental treatments. Therefore, the experimental results of quasi-experimental research are easier to relate to real situations, and are more realistic [30]. For studies that are not easy to conduct with true experimental design, quasi-experimental research methods can be used to design control methods to reduce the influence of some factors on the validity of the experiment [31]. Landscape architecture conservation courses are important for the development of students' awareness of landscape conservation. The purpose of this study is to investigate the multisensory SV-IVR learning system in a landscape architecture conservation course and its effects on student learning achievements, learning model satisfaction, technology acceptance, flow experience and learning attitudes.

3.1. Participants

Sixty students (30 boys and 30 girls) from a Chinese middle school were selected for this experiment. The age of the students was between 12 and 13 years old. They already had some self-judgmental ability and no invalid data due to insufficient cognition occurred during the pre-test and post-test of the experiment. Thirty students were randomly selected as the experimental group (16 boys and 14 girls) and 30 students as the control group (14 boys and 16 girls). The experimental group was taught using the multisensory SV-IVR landscape architecture conservation course learning system, while the control group was taught using the traditional teaching model. All students were taught by a teacher with many years of experience in landscape architecture conservation education, and the students' ages did not vary more than one year up or down. All students had no major differences in their knowledge of landscape architecture conservation, and all were aware of virtual reality technology. However, they had no experience in learning with virtual reality technology or prior knowledge of the SV-IVR learning system.

3.2. Measurement Scale Instruments (Tests and Questionnaires)

The measurement instruments used in this study included a pre-test, a post-test, a learning model satisfaction questionnaire, a learning attitude questionnaire, a technology acceptance questionnaire, a flow experience questionnaire and a learning achievement questionnaire. Instead of using a "strongly disagree to strongly agree" description, we used a numerical scale from 1 to 5 to reflect the level of approval [32].

The pre-test and post-test of the experiment used tests provided by teachers with many years of experience in landscape architecture conservation education. The purpose of the pre-test of the experiment was to assess students' prior knowledge; the total score was 100 points, containing 10 multiple-choice questions and 10 true-or-false questions. The purpose of the knowledge post-test was to assess the concepts and knowledge that students learned during the course. This section also had total score of 100 points and contained 10 multiple-choice questions and 10 true-or-false questions. In addition, two experts in the field were invited to verify that the test was an accurate assessment of student learning outcomes. The KR-20 of the pre- and post-tests was 0.86 and 0.91, respectively, indicating an acceptable internal consistency (Cortina, 1993) [33].

The learning model satisfaction questionnaire was adapted from a survey developed by Chu, H.C., Hwang, G.J., Tsai, C.C. and Tseng, J.C.R. It consists of nine questions, such as: "This learning task made me understand the content better" and "I made an effort to learn to observe the differences in this learning task" [34].

The technology acceptance questionnaire was adapted from a survey developed by Hwang, G.J., Yang, L.H. and Wang, S.Y. It consisted of 13 questions, such as "I feel that using such a learning style (or system) makes the learning activities more informative" and "I feel that using such a learning style (or system) is helpful for me to learn new things" [35].

The low experience questionnaire was adapted from a survey developed by Pearce, J.M., Ainley, M. and Howard, S. It consists of eight questions, such as "During this activity, I was sure that everything I did would turn out as I expected" and "I was strongly engaged in this activity" [36].

The learning attitudes questionnaire was adapted from a survey developed by Hwang, G.J., Yang, L.H. and Wang, S.Y. It consists of seven questions, such as "I find studying this course interesting and valuable" and "I want to learn more and observe more about this course" [35].

3.3. Landscape Architecture Conservation Course Multisensory SV-IVR Learning System

In order to better apply the SV-IVR to a landscape architecture conservation course, this study developed an SV-IVR learning system for a landscape planning and conservation course with a multisensory integration of visual, auditory and olfactory senses. This study used the EduVenture VR platform developed by a university in Hong Kong as a development tool (EduVenture VR is a platform that specializes in the editing and design of VR teaching resources), as shown in Figure 1 [37]. Through this development tool, we built the SV-IVR learning system. The whole learning system is very simple and easy to understand. The system contains three modules: the learning material editing module, the database module and SV-IVR learning. The teacher sets up teaching materials on the EduVenture VR platform; then, students can learn through the EduVenture VR application. In the learning material editing module, teachers can import pictures and videos taken through 360-degree panoramic cameras or obtained from other sources, and then process teaching materials and design teaching processes according to teaching requirements. Depending on the needs of the landscape architecture conservation course, the teacher can import audio and questions needed for the teaching process in the editing module for the panoramic images or videos. At the same time, the teacher can also use the data code to control when to release scents, play the ambient sounds, etc., as a way to improve the immersion of the learning system. The teacher-side display screen is shown in Figure 2.

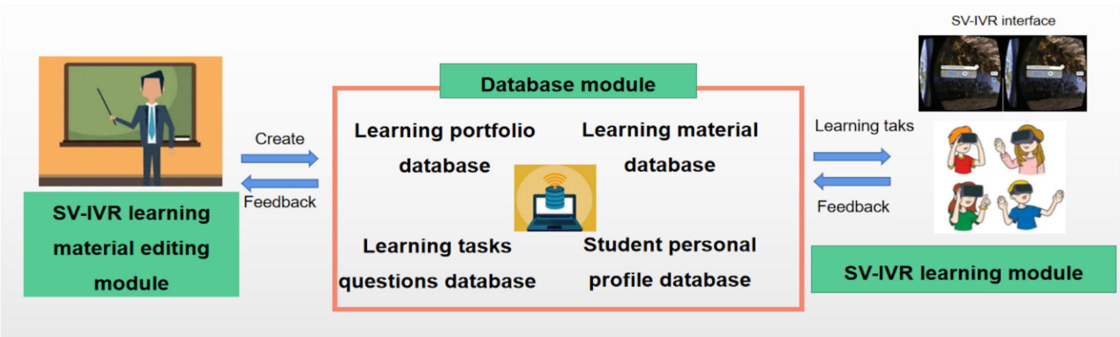

Figure 1. SV-IVR learning system.

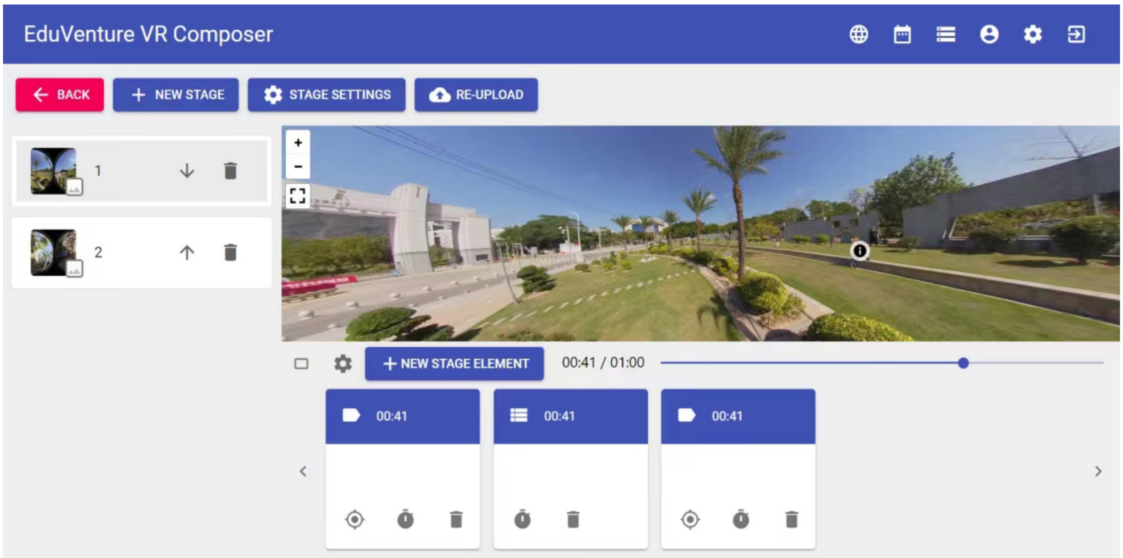

Figure 2. Teacher editing module.

The database module, a web-based cloud database, contains student personal information, student grades and previously stored data. The database module is linked to the EduVenture VR platform and the student's information data is partially stored in the platform. Teachers can search through this database if they want to check students' information and academic performance, etc.

In the multisensory SV-IVR learning module, students use their cell phones and Google Cardboard for SV-IVR learning. Students enter the virtual world and immerse themselves in the natural landscape environment according to the teaching schedule set by the teacher. They can learn in a virtual environment and complete the questions set by the teacher, as well as the knowledge test in the system, as shown in Figure 3.

In the multisensory SV-IVR learning system, students engage in a multi-level cycle of learning. Students follow the teacher's instructional design and the content guidance of the video and audio teaching materials. For example, in the case of the causes of landscape pollution, teachers include pre-recorded video and audio files when designing teaching materials (audio includes ambient sounds recorded on site and other audio material needed for teaching). After a period of study, the system automatically presents a question and asks students to record audio to answer the teacher's questions (Figure 4). The pop-up question is "What are the main causes of pollution in this area", and students answer based on their knowledge (Figure 5). Only when they have answered the question correctly and finished recording the audio can they jump to the next learning session; otherwise, they have to pass through the session again.

Figure 3. SV-IVR learning system interface.

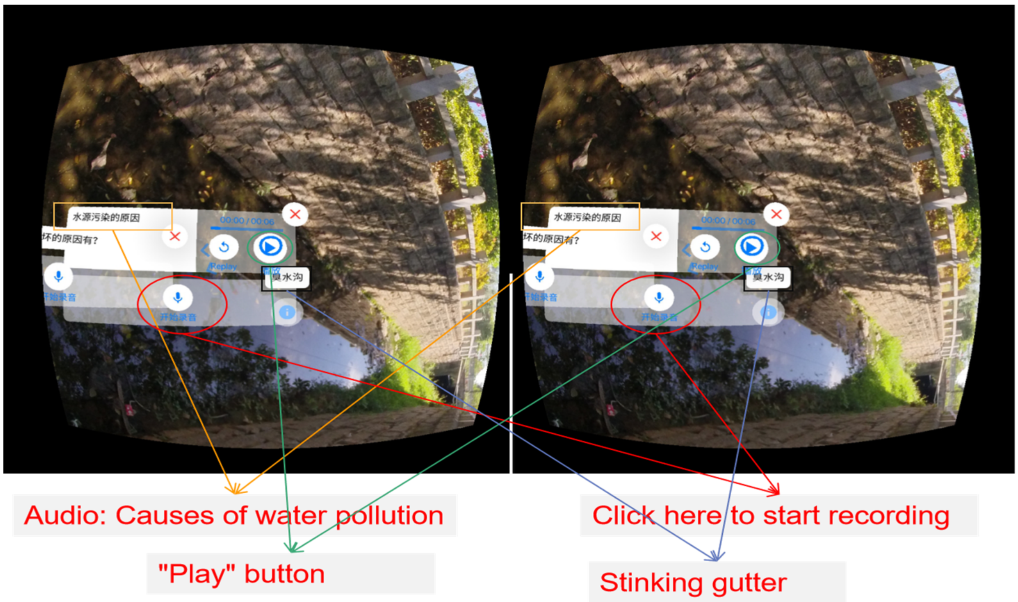

Figure 4. Screenshot of SV-IVR learning system: teaching audio and audio recording.

In the SV-IVR landscape architecture conservation learning system, to make the system more immersive, this study also innovatively added elements related to the senses of smell and hearing. The teacher sets fixed time points when setting up the teaching materials, and the bottle storing the gas releases the gas by opening a valve controlled by computer code, or is manually operated by the teacher. At the same time, the teacher adds pre-recorded sound materials of the real environment and plays the sound while releasing the gas, forming a fusion of vision, smell and hearing, so that students can experience the live situation in an immersive manner. The multisensory SV-IVR learning system can make the learning system more immersive by integrating visual, olfactory and auditory senses. Students will have a more intense learning experience, which can effectively improve students' interest in and efficiency of learning, and can also effectively improve students' learning performance, as shown in Figures 6 and 7.

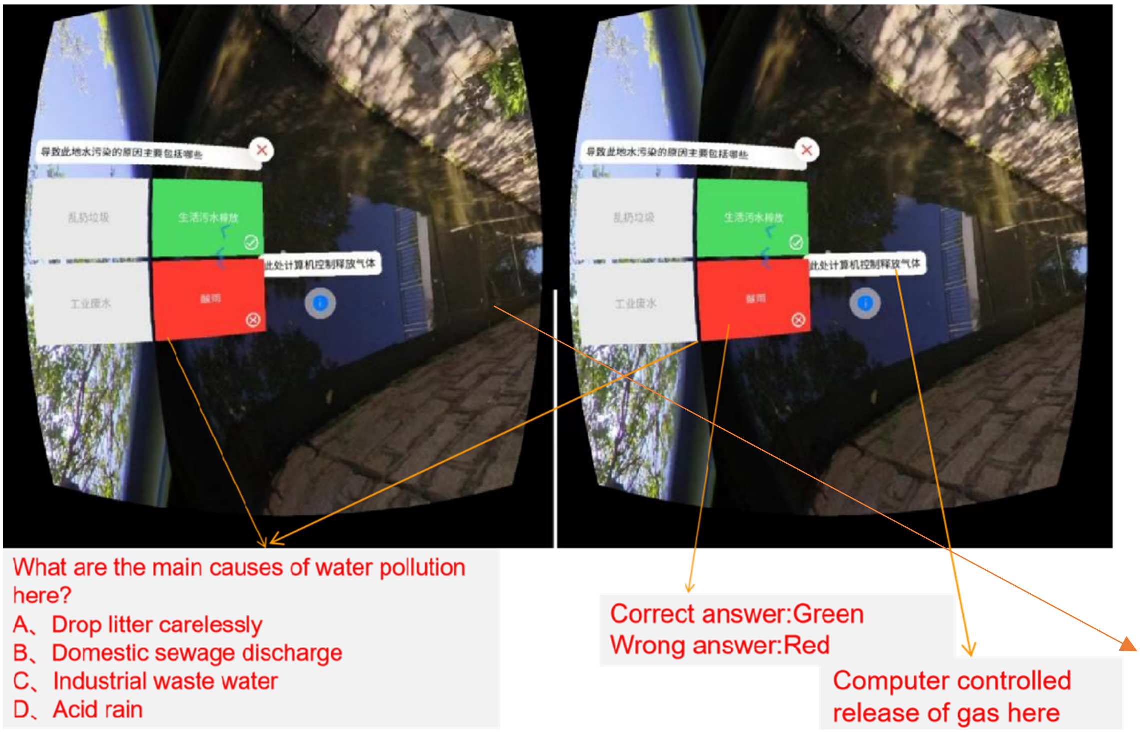

Figure 5. Screenshot of SV-IVR learning system: students answering questions.

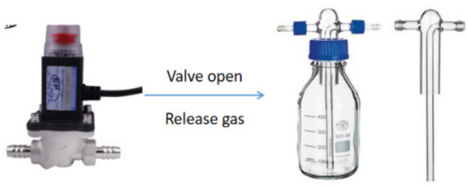

Figure 6. Schematic diagram of olfactory elements of SV-IVR learning system.

Figure 7. Screenshot of SV-IVR learning system: gas release.

3.4. Experimental Procedure

Figure 8 shows the detailed process of the experiment. In total, 60 students were divided into two groups. The experimental group used the multisensory SV-IVR learning system to learn with Google Cardboard; an explanation of SV-IVR was presented through smartphones after entering the learning system. The control group used a traditional teaching model using traditional multimedia lectures, including PowerPoint presentations, pictures and video presentations and the teacher giving the lecture. Before the experiment started, 60 students were given a pre-experimental test consisting of a questionnaire with four sections: learning model satisfaction, technology acceptance, flow experience and learning attitudes, with the process taking about 30 min. In order to eliminate the psychological impact of the different teaching modes on the students, the two groups of students were not informed of the different teaching modes in class from the beginning to the end of the experiment. After completing the pre-experimental test, the teacher taught the two classes for 90 min. Considering that teachers may not have a high level of mastery of the SV-IVR system, we let them learn the system before the experiment started to ensure that there were no errors caused by improper teacher operation. After the lectures were completed, we organized a course exam for students on landscape planning and conservation, which included mastery of landscape architecture conservation methods and skills and suggestions for landscape architecture conservation. After the course exam, all students filled out a post-lab test questionnaire, with the process taking 60 min.

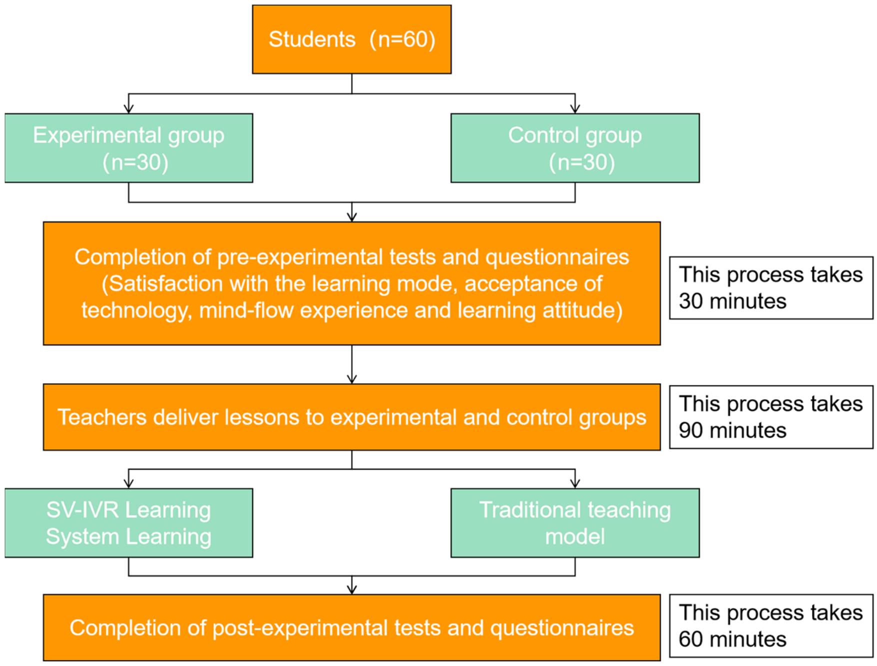

Figure 8. Experiment process.

4. Results

4.1. Test and Questionnaire Results

We used Cronbach's alpha to test the reliability of the questionnaire. According to George and Mallery [38], the scale of Cronbach's alpha value is: >0.9 excellent; >0.8 good; 0.7 acceptable; 0.6 questionable; and >0.5 poor. As shown in Table 1, according to the test results, the reliability of the results obtained in this study is good [39].

Table 1. The Cronbach's alpha results of the test and questionnaires.

	Pre-Test	Post-Test	Learning Model Satisfaction	Technology Acceptance	Flow Experience	Learning Attitude
Cronbach's alpha	0.86	0.91	0.90	0.92	0.90	0.87

The Cronbach's alpha values of the pre-test and post-test were 0.86 and 0.91, respectively, showing acceptable internal consistency (Cortina, 1993) [33].

The Cronbach's alpha value of learning model satisfaction was 0.90.
The Cronbach's alpha value of technology acceptance was 0.92.
The Cronbach's alpha value of flow experience was 0.90.
The Cronbach's alpha value of learning attitude was 0.87.

This means that we can use these questionnaires with good reliability to conduct the survey.

4.2. Analysis of Learning Achievements

In order to exclude the influence of scores before the questionnaire, ANCOVA was used to evaluate students' academic performance after learning activities. The Shapiro–Wilk test was used to test the normality of data. The test value was 0.993, $p = 0.704$, which indicates that the samples in this study have a normal distribution, as shown in Table 2.

Table 2. Normality test.

	Kolmogorov–Smirnov			Shapiro–Wilke		
	Statistics	**Free Degree**	**Significance**	**Statistics**	**Free Degree**	**Significance**
Total score	0.051	60	0.200	0.993	60	0.704

a. Riley's significance correction

The Levene test for determining the homogeneity of variance shown in Table 3 was not violated ($F = 1.977$, $p > 0.05$). This shows that the null hypothesis is valid and the variances between groups are equal, so one-way ANCOVA was conducted.

Table 3. Levene equivalence test for error variance.

		Levene Statistic	Degree of Freedom 1	Degree of Freedom 2	Significance
Total score	Based on average values	1.977	1	58	0.165
	Based on median	1.740	1	58	0.192
	Based on median and with adjusted degrees of freedom	1.740	1	45.655	0.194
	Based on mean value after clipping	1.957	1	58	0.167

The original hypothesis of equal error variances of the dependent variable in each group was tested.
a. Dependent variable:total score
b. Design: intercept + your group.

From the ANCOVA results, the mean for the experimental group was 93 with a standard error of 1.45, and the mean for the control group was 86, with a standard error of 2.098, as shown in Table 4. A significant difference was found between the post-test scores of the two groups ($F = 38.33$, $p < 0.01$). The experimental group had a significantly higher post-test score than the control group. In other words, students who learned using the SV-IVR learning system showed significantly better academic performance than those who learned using traditional learning methods. Furthermore, the effect size of the learning method (η^2) was 0.7 > 0.14, indicating a large effect size.

Table 4. ANCOVA results of academic achievement.

Group	N	Mean	SD	SE	*F*	η^2
Experimental group	30	93	7.944	1.45	12.33 **	0.7
Control group	30	86	11.492	2.098		

** $p < 0.01$.

4.3. Analysis of Learning Model Satisfaction

In order to exclude the influence of scores before the questionnaire, ANCOVA was used to evaluate the effectiveness of students' academic performance after learning activities. A Shapiro–Wilk test was used to test the normality of data. The test value was 0.901, $p = 0.261$, which indicates that the samples in this study have a normal distribution, as shown in Table 5.

Table 5. Normality test.

	Kolmogorov–Smirnov			Shapiro–Wilke		
	Statistics	**Free Degree**	**Significance**	**Statistics**	**Free Degree**	**Significance**
Satisfaction with the learning model	0.091	60	0.075	0.901	60	0.061

a. Riley's significance correction

The Levene test for determining the homogeneity of variance shown in Table 6 was not violated ($F = 13.064$, $p > 0.05$). It showed that the null hypothesis is valid and the variances between groups are equal, so one-way ANCOVA was conducted.

Table 6. Levene equivalence test for error variance.

		Levene Statistics	Degree of Freedom 1	Degree of Freedom 2	Significance
Satisfaction with the learning model	Based on average values	13.064	1	58	0.001
	Based on median	10.116	1	58	0.002
	Based on median and with adjusted degrees of freedom	10.116	1	43.703	0.003
	Based on mean value after clipping	11.849	1	58	0.001

The original hypothesis of equal error variances of the dependent variable in each group was tested.
a. Dependent variable: satisfaction with the learning model
b. Design: intercept + your group.

From the ANCOVA results, the mean for the experimental group was 26.73 with a standard error of 0.267; the mean for the control group was 19.5 with a standard error of 0.615, as shown in Table 7. A significant difference was found between the post-test scores of the two groups ($F = 116.309$, $p < 0.01$). The experimental group had a significantly higher post-test score than the control group. In other words, students studying with the SV-IVR learning system were more satisfied with the learning model than those studying with traditional learning methods. Furthermore, the effect size of the learning method (η^2) was 0.667 > 0.14, indicating a large effect size.

Table 7. ANCOVA results of learning model satisfaction.

Group	N	Mean	SD	SE	F	η^2
Experimental group	30	26.73	1.461	0.267	116.309 **	0.667
Control group	30	19.5	3.371	0.615		

** $p < 0.01$.

4.4. Analysis of Technology Acceptance

In order to exclude the influence of scores before the questionnaire, ANCOVA was used to evaluate the effectiveness of students' academic performance after learning activities. A Shapiro–Wilk test was used to test the normality of data. The test value was 0.995, $p = 0.601$, which indicates that the samples in this study have a normal distribution, as shown in Table 8.

Table 8. Normality test.

	Kolmogorov–Smirnov			Shapiro–Wilke		
	Statistics	**Free Degree**	**Significance**	**Statistics**	**Free Degree**	**Significance**
Technology acceptance	0.088	60	0.111	0.995	60	0.701

a. Riley's significance correction

The Levene test for determining the homogeneity of variance shown in Table 9 was not violated ($F = 5.004$, $p > 0.05$). It showed that the null hypothesis is valid, and the variances between groups are equal, so one-way ANCOVA was conducted.

Table 9. Levene equivalence test for error variance.

		Levene Statistics	Degree of Freedom 1	Degree of Freedom 2	Significance
Technology acceptance	Based on average values	5.004	1	58	0.000
	Based on median	6.285	1	58	0.000
	Based on median and with adjusted degrees of freedom	5.285	1	41.412	0.000
	Based on mean value after clipping	5.224	1	58	0.000

The original hypothesis of equal error variances of the dependent variable in each group was tested.
a. Dependent variable: technology acceptance
b. Design: intercept + your group.

From the ANCOVA results, the mean for the experimental group was 60.13 with a standard error of 1.45; the mean for the control group was 53.47 with a standard error of 0.63, as shown in Table 10.A significant difference was found between the post-test scores of the two groups ($F = 185.148$, $p < 0.01$). The experimental group had significantly higher post-test scores than the control group. In other words, students who studied using the SV-IVR learning system were more receptive to technology than those who studied using traditional learning methods. Furthermore, the effect size of the learning method (η^2) was 0.91 > 0.14, indicating a large effect size.

Table 10. ANCOVA results of technology acceptance.

Group	N	Mean	SD	SE	F	η^2
Experimental group	30	60.13	6.285	1.147	185.148 **	0.91
Control group	30	53.47	3.451	0.63		

** $p < 0.01$.

4.5. Analysis of Flow Experience

In order to exclude the influence of scores before the questionnaire, ANCOVA was used to evaluate the effectiveness of students' academic performance after learning activities. A Shapiro–Wilk test was used to test the normality of data. The test value was 0.998, $p = 0.418$, which indicates that the samples in this study have a normal distribution, as shown in Table 11.

Table 11. Normality test.

	Kolmogorov–Smirnov			Shapiro–Wilke		
	Statistics	**Free Degree**	**Significance**	**Statistics**	**Free Degree**	**Significance**
Flow experience	0.034	60	0.007	0.998	60	0.418

a. Riley's significance correction

The Levene test for determining the homogeneity of variance shown in Table 12 was not violated ($F = 8.179$, $p > 0.05$). This shows that the null hypothesis is valid, and the variances between groups are equal, so one-way ANCOVA was conducted.

Table 12. Levene equivalence test for error variance.

		Levene Statistics	Degree of Freedom 1	Degree of Freedom 2	Significance
Flow experience	Based on average values	8.179	1	58	0.000
	Based on median	9.088	1	58	0.000
	Based on median and with adjusted degrees of freedom	8.088	1	49.322	0.000
	Based on mean value after clipping	8.295	1	58	0.000

The original hypothesis of equal error variances of the dependent variable in each group was tested.
a. Dependent variable: flow experience
b. Design: intercept + your group.

From the ANCOVA results, the mean for the experimental group was 32.3 with a standard error of 0.528; the mean for the control group was 26.4 with a standard error of 0.351, as shown in Table 13.A significant difference was found between the post-test scores of the two groups ($F = 180.952$, $p < 0.01$). The experimental group had a significantly higher post-test score than the control group. In other words, students who studied using the SV-IVR learning system demonstrated significantly better scores on flow experience than those who studied using traditional learning methods. Furthermore, the effect size of the learning method (η^2) was 0.892 > 0.14, indicating a large effect size.

Table 13. ANCOVA results of flow experience.

Group	N	Mean	SD	SE	F	η^2
Experimental group	30	32.3	2.891	0.528	180.952 **	0.892
Control group	30	26.4	1.923	0.351		

** $p < 0.01$.

4.6. Analysis of Learning Attitudes

In order to exclude the influence of scores before the questionnaire, ANCOVA was used to evaluate the effectiveness of students' academic performance after learning activities. A Shapiro–Wilk test was used to test the normality of data. The test value was 0.983, $p = 0.104$, which indicates that the samples in this study have a normal distribution, as shown in Table 14.

Table 14. Normality test.

	Kolmogorov–Smirnov			Shapiro–Wilke		
	Statistics	**Free Degree**	**Significance**	**Statistics**	**Free Degree**	**Significance**
Learning attitude	0.276	60	0.000	0.983	60	0.104

a. Riley's significance correction

The Levene test for determining the homogeneity of variance shown in Table 15 was not violated ($F = 7.326$, $p > 0.05$). This shows that the null hypothesis is valid, and the variances between groups are equal, so one-way ANCOVA was conducted.

Table 15. Levene equivalence test for error variance.

		Levene Statistics	Degree of Freedom 1	Degree of Freedom 2	Significance
Learning attitudes	Based on average values	7.326	1	58	0.000
	Based on median	8.332	1	58	0.000
	Based on median and with adjusted degrees of freedom	7.332	1	40.118	0.000
	Based on mean value after clipping	7.332	1	58	0.000

The original hypothesis of equal error variances of the dependent variable in each group was tested.
a. Dependent variable: learning attitude
b. Design: intercept + your group.

From the ANCOVA results, the mean for the experimental group was 28.83 with a standard error of 0.48; the mean for the control group was 21.23 with a standard error of 0.257, as shown in Table 16. A significant difference was found between the post-test scores of the two groups ($F = 136.324$, $p < 0.01$). The post-test scores of the experimental group were significantly higher than those of the control group. In other words, students who studied using the SV-IVR learning system had a better attitude towards learning than those who studied using traditional learning methods. Furthermore, the effect size of the learning method (η^2) was 0.902 > 0.14, indicating a large effect size.

Table 16. ANCOVA results of learning attitudes.

Group	N	Mean	SD	SE	*F*	η^2
Experimental group	30	28.83	2.627	0.48	136.324 **	0.902
Control group	30	21.23	1.406	0.257		

** $p < 0.01$.

5. Discussion

The results of the study showed that students using the multisensory SV-IVR landscape architecture conservation learning system achieved higher scores in terms of learning achievements, learning model satisfaction, technology acceptance, flow experience and learning attitudes than students using traditional teaching methods. This study aims to integrate SV-IVR technology with landscape architecture conservation courses, which is expected to have a good influence on the development of landscape architecture conservation courses. The multisensory SV-IVR learning system solves some of the problems that exist in the application of virtual reality technology, such as cost, high hardware requirements and the inconvenience of designing courses for teachers. The innovation of this study is that there are few studies that have applied SV-IVR to landscape planning and conservation courses. The learning system used in this study includes visual and auditory elements, with the innovative addition of an olfactory element as a way to integrate multiple sensory experiences. This makes the learning system more immersive, which is conducive to increasing student engagement and has a better effect on student learning.

In terms of learning achievements, the study verified the effectiveness of the multisensory SV-IVR learning system for landscape architecture conservation. Students who studied with this learning system had higher learning achievements than those who studied with the traditional teaching model. At the same time, students who studied with the SV-IVR learning system were more satisfied with the learning model than those who studied with the traditional teaching model. They had better experience of learning achievements, learning model satisfaction, technology acceptance, flow experience and learning attitudes. Using the multisensory SV-IVR landscape architecture conservation learning system, students can become more immersed in classroom instruction. Furthermore, because the learning system is a multi-level cycle, teachers can design instructional materials in such a way that they can effectively ensure that students are able to meet the teacher's expectations. A student who does not meet the instructional objectives and does not successfully complete the instructional task will not be able to move on to the next unit of study. This also stimulates curiosity to a certain extent, and students will be more engaged in learning because they are looking forward to moving on to the next session. The method is effective in increasing students' motivation, which can help them better understand the teaching tasks and achieve the teacher's teaching objectives. As a result, students' learning achievements are improved. This is only an experiment with 60 people, so there may be some limitations and we will continue to study this subject in depth.

In terms of learning model satisfaction, multisensory SV-IVR learning system is different from the traditional teaching, allowing students to more deeply participate in learning. It is different from the traditional teaching mode in which the teacher shows and explains and students passively learn knowledge. By adopting this learning mode, students become the dominant player in the learning process. Through interviews with students after the class, students in the experimental group said that they were fully engaged in learning when adopting this learning mode. Their learning efficiency was improved, their learning experience was very good, and they hoped that this teaching mode would be adopted in other courses; students in the control group said that they were easily distracted during the class. They were not attracted by the teaching mode because some of the content taught by the teacher was obscure and difficult to understand. As a result, the learning effect was not very good during the class.

In terms of technology acceptance, the results showed that students in the experimental group were more receptive to the use of technology in teaching and learning than students in the control group, and that the multisensory SV-IVR learning system was easy to operate and lightweight, and did not add to the burden of the learning process, but helped to simplify it. Interviews with students in the experimental group indicated that learning with the multisensory SV-IVR learning system was easier and more interesting than in the past, and they expected more technology to be incorporated into the curriculum in the future; students in the control group indicated that the traditional teaching mode could not satisfy their curiosity, and they hoped that more technology elements could be added to the curriculum in the future, which could effectively improve their learning performance.

In terms of flow experience, the results showed that students in the experimental group had a better experience than those in the control group. Through interviews with students, students in the experimental group said they were able to clearly understand what they needed to learn in class and what they should do in the course. They were able to devote themselves to learning, while students in the control group said they were unable to clearly understand what they needed to focus on in class because the teacher was talking about too many things, and they did not know what they should do, which led to their grades not improving effectively.

In terms of learning attitudes, the results showed that students in the experimental group had better learning attitudes than those in the control group. The use of the multisensory SV-IVR learning system in the course was novel and interesting for students, and can stimulate students' learning initiative and motivation, thus improving their learning attitudes. Through interviews with the students after the class, the students in the experimental group said that they were integrated into the classroom during the learning process due to the inclusion of technological elements. It was as if they had walked into a large forest during the class, which greatly increased their interest in learning. In the learning process, if they could not pass the test set by the teacher, then they had to continue learning, which also stimulated their motivation. They hoped that they could pass the test, so they were more serious when studying. In addition, through the teachers' well-designed teaching materials, they clearly understood what they needed to do in the learning process, which was also conducive to their learning achievements. Therefore, most of the students said they were very active in learning in class, and they also took the initiative to collect relevant knowledge materials for self-study after class. In contrast, students in the control group said that they were completely passive in receiving knowledge in class and their interest in the course was low, so they were less active in class. They were only willing to spend time on completing after-class assignments in their spare time, and they were not willing to spend significant time searching for relevant materials for self-study.

In addition, we implemented a system to automatically release additional olfactory and auditory materials through computer code in the teacher's teaching material editing module. To a certain extent, this solved the problem of poor immersion in the teaching tools and poor student experience. Through this course, students obviously increased their interest in the process, and in the post-class interviews, students also reported that they felt as if they had really walked into the forest during the class, heard the sounds of the forest, smelled the odor and felt as if they walked next to a beautiful landscape. At the same time, students were able to experience the adverse effects of the destruction of the landscape in a more realistic way, and were able to see, hear and smell the environment after the destruction, which was in strong contrast to the previous landscape. By setting up such a comparison, it is hoped that this will motivate students to strive to learn the skills of landscape planning and conservation, and effectively raise awareness of landscape conservation.

6. Conclusions

This study innovatively applied virtual reality technology in a landscape architecture conservation course to create a multisensory SV-IVR landscape architecture conservation learning system, analyzing the impact on students of the multisensory SV-IVR landscape architecture conservation learning system and traditional learning methods. The results of the study show that the SV-IVR learning system can improve student performance, increase satisfaction with the learning model, improve technology acceptance, enhance the flow experience, stimulate students' interest in learning and improve their attitude to learning. The innovation of this study is that there are few studies that have applied VR (especially SV-IVR) to landscape planning and conservation courses, and unlike previous SV-IVR teaching, we added an olfactory element to the study for a multisensory system integration that will hopefully be effective in enhancing students' experience and immersion. As such, this is a relatively new experiment for both landscape planning and conservation courses and SV-IVR education.

The goal of landscape architecture conservation courses is not only to let students discover and feel the beauty of specific and limited places, but also to let students discover and experience the ancient, solid, vast and eternal meaning of nature, and to cultivate a sense of life and the universe. Therefore, immersive teaching through virtual reality technology has a significant effect on students' comprehensive cognition, helping them understand the natural landscape world through a visual and artistic process and cultivating their awareness of nature and the concept of landscape conservation.

The main contribution of this study is to help landscape design course teaching and learning by developing a multi-sensory SV-IVR learning system for landscape architecture conservation courses. The combination of a landscape architecture conservation course with SV-IVR is innovative. The virtual reality landscape generated by VR technology can break through the limitation of two-dimensional scenes and overcome the limitations of the site. The SV-IVR learning system can provide panoramic and dynamic perceptual information to teachers and students. At the same time, the novelty of this study lies in the inclusion of olfactory and auditory elements in the SV-IVR teaching mode, which can be controlled to play pre-recorded audio files at specific stages and release harmless odors that can stimulate the sense of smell. For example, if the virtual environment is the Amazon rainforest, the audio file can be the song of birds and beasts, and the smell can be the fresh air and the fragrance of flowers and plants. When the virtual environment is a polluted river, the smell can be similar to the smell of decay. By providing a more comprehensive sensory experience of hearing, seeing and smelling, students can feel the difference between the natural landscape before and after it is destroyed.

In addition, in the post-COVID-19 pandemic era, offline education has suffered and traditional online education faces a range of problems, such as decreased student attention, poor learning outcomes, low motivation, difficulty grading, and lack of the contextual environment needed for the course [40]. Innovative education technology is a developing trend. The SV-IVR learning system provides a new perspective for thinking about landscape architecture conservation courses and verifies the feasibility of virtual reality technology in the field of education, as well as its advantages. It will also inspire the innovation of future landscape design education methods, injecting new vitality into course teaching and learning methods, which is conducive to cultivating better talent. The multisensory SV-IVR landscape architecture conservation learning system is more practical and cost effective than other teaching methods, and is also more environmentally friendly, as teachers and students do not need to travel and produce carbon emissions. As a VR digital course itself, the online course also serves as a sustainable teaching resource that can be re-used for learning and is more in line with the concept of green sustainability.

However, there are some limitations to this study. Firstly, the length of the experiment was short; future studies may consider long-term experiments, such as conducting a semester-long experiment and verifying the validity and sustainability of the results. Secondly, there may be limitations due to the number of participants in the experiment. Future researchers may consider expanding the sample size to further improve the accuracy of the experiment. Thirdly, there are differences in students' learning styles, learning characteristics, etc., and these factors may also affect student learning performance. At the same time, different teaching resources may also affect students' learning outcomes, which need to be further explored. Future research can expand the breadth and depth of the study. Finally, the incorporation of new technology may bring a series of problems. For example, in this study, there were individual students who experienced damage to the equipment and did not adapt to the equipment during use, because it was their first exposure to the new technology. Future research should consider how to solve these problems.

Author Contributions: Conceptualization, W.W. and Z.Z.; methodology, W.W. and A.D.; software, W.W.; validation, W.W., Z.Z. and J.L.; formal analysis, W.W.; investigation, W.W., Z.Z. and J.L.; resources, W.W. and A.D.; data curation, A.D. and J.L.; writing—original draft preparation, W.W.; writing—review and editing, W.W., Z.Z. and A.D.; visualization, W.W.; supervision, Z.Z.; project administration, W.W. and Z.Z. All authors have read and agreed to the published version of the manuscript.

Funding: Supported by Social Science Foundation Project of Fujian Province, China (Funding Number: FJ2022C071).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restrictions, e.g., privacy or ethical.

Acknowledgments: The authors thank Morris Siu-Yung Jong (Department of Curriculum and Instruction and the Director of Centre for Learning Sciences and Technologies, at the Chinese University of Hong Kong) for the technical support.

Conflicts of Interest: The authors declare no conflict of interest.

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