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A Virtual Experience System of Bamboo Weaving for Sustainable Research on Intangible Cultural Heritage Based on VR Technology

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Abstract: As an important national cultural treasure, intangible cultural heritage (ICH) faces certain problems in inheritance and sustainability. With the development of digital technology, the increasing research and application of virtual reality technology in ICH have been presented. This paper proposes a virtual experience system for Dongyang bamboo weaving, a traditional form of ICH craftsmanship, to display its historical background, cultural connotation, and technical craftsmanship. The learning module of the system is evaluated through the comparative experiments by 8 subjects. From the experimental data, compared with the computer, the average time for subjects to learn bamboo weaving in the system is shorter. The results of the questionnaire indicate that the learning module arouse their interest in bamboo weaving. The result shows the system is able to create an immersive and interactive scene for the users to understand bamboo weaving culture and learn the skills, which may encourage the sustainable development of bamboo weaving culture from the perspective of diffusion and provide research methods for other studies on traditional craftsmanship of ICH.

Keywords: intangible cultural heritage; bamboo weaving; virtual reality; user experience; sustainable development

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1. Introduction

Intangible cultural heritage (ICH) is the wisdom crystallization of human civilization and one of the important carriers of national culture, representing the civilization of a country and the spirit of a nation [1]. As the deposit and crystallization of important cultural wealth accumulated over a long period of time, ICH not only reflects the development history of national culture [2] but also contains rich cultural connotation, which is highly representative of the masses and regions [3]. However, due to the passage of time and changes, as well as the "intangible" characteristics of ICH itself, its living space and market development have been seriously affected, and thus some ICH are slowly dying out and gradually fading out of the public view. As a cultural treasure of a nation, ICH is crucial to the realization of a sustainable society. In the context of the new era, how to protect and inherit ICH so as to maintain a sustainable development has become an urgent problem.

As a local craft of Dongyang City, Zhejiang Province, Dongyang bamboo weaving is one of the first National Intangible Cultural Heritage items [4]. After years of historical precipitation, it has formed its own unique style and superb techniques, which not only has high artistic value but also inherits traditional culture [5]. In the past, bamboo weaving was an essential tool for human production and living, but nowadays, with the development of technology, the emergence of more convenient and low-cost materials has gradually replaced the bamboo crafts, making it disconnected from the public lifestyle. Because of the difficulties in inheritance and diffusion as well as the weakness of cultural soil [6], the inheritance and protection of Dongyang bamboo weaving has fallen into a difficult situation. In the modern communication context, in order to raise the public awareness of

appreciation and protection for bamboo weaving, it is particularly important to study what kind of display modes can make the public recognize bamboo weaving, approach it, and create new links with it. Expanding the influence of bamboo weaving culture is also the source of motivation for the sustainable development of bamboo weaving.

In recent years, digital diffusion and protection have gradually become the focus of attention in cultural heritage sessions in the world. Virtual reality technology, also known as VR technology, developed in the 1990s, refers to the creation of a virtual space through computer technology [7] where the users can interact with each other, finally lead to an immersive effect. As a new type of audiovisual technology and communication medium, virtual reality technology can change the traditional display form of ICH, reshape the display space, and bring new concepts of diffusion to ICH; meanwhile, it provides opportunities for the public to understand and approach to ICH. The existing digital display of ICH is mostly concentrating on the aspect of digital text, audio, and video, which lacks the feeling of immersion and experience. For the integration of ICH and virtual reality technology, related research is rapidly developing, but the practical applications are still insufficient, especially the one on the theme of bamboo weaving diffusion and development.

This paper proposes a virtual experience system for Dongyang bamboo weaving, including introduction of culture, display, and learning of bamboo weaving, and conducts an experimental evaluation in the part of learning. It aims to use VR technology as a medium to broaden the communication path of bamboo weaving and provide new solution for the communication and sustainable development of ICH.

2. Related Works

2.1. Study on Digitization of ICH

In recent years, digital technology has been rapidly developed and applied to many research fields, but a unified definition of digitization of ICH has not been formed yet [8]. In 2009, Chinese scholar Yaoxi Wang [9] defined "digitization of cultural heritage" as "the use of digital technologies such as digital acquisition, digital storage, digital processing, digital display and digital diffusion to convert, reproduce and restore cultural heritage into a shareable and renewable digital form". At present, the research on digitization of ICH mainly focuses on three aspects: mechanism of protection [10], display and diffusion [11], and inheritance and development [12].

From the perspective of protection, the main research methods are as follows: (1) Digital technology is to be used to systematically record skills and the experience of the inheritors combined with modern storage technologies such as databases, data management, and data retrieval to establish a complete and orderly database with standardized management [13–16], and (2) image recognition technology and 3D modeling are to be used to restore and record the operation process of ICH skills and crafts making [17–20].

From the perspective of display and diffusion, the digitization of ICH is mainly based on digital repositories through the Internet, integrated media, artificial intelligence, and other media to empower applications in industries such as cultural and museum industries, tourism, and enterprise management. The specific forms of digitization of ICH mainly focus on digital image-based content display, such as digital restoration of scenes in folklore museums, VR panoramic immersive experiences [21–23], AR interactive scene construction [24–28], virtual platform building [29,30], animation game application development [31–37], and network media content display [38–40], such as the live broadcast of inheritors' work sites through short video platforms.

The digital inheritance and innovation of ICH can generate new value from the future digitally empowered ICH projects. This means building a smart industrial system from the application of digital storage technology to poverty alleviation in digital industry, smart travel system [29,41,42], online intangible digital education [43,44], product-aided design systems [45–48], and so on. Numerous cultural contents, humanistic spirit, and economic values are created accordingly to adapt to the development of the era. For example, Dan

Xu [49] believes that the combination of lion dance culture and realistic themes in the film "I Am What I Am" makes the spiritual culture of ICH diffused through the digital way.

2.2. Application of VR Technology in the Study of ICH

Virtual reality technology provides support for the protection, diffusion, and innovation of ICH. Jiexiao Tang and Chen Shen [50] used Unreal Engine 3 to design a scene roaming display platform for the ancient village of Hongcun in Anhui Province. Deng [51] analyzed the production techniques of Yixing Zisha pottery and proposed a strategy of virtual roaming experience used in archaeological and architectural sites. Wenhu Peng [52] analyzed the problems of the existing digital platform of ICH and proposed a strategy of using VR technology to build a 3D model database and create a virtual exhibition hall. Bin Zheng [53] and other scholars used the VR technology to research the digitization of porcelain craftsmanship of Yuezhou Kiln to explore new ideas of inheritance of ICH. Yingchao Sun [54] and other scholars elaborated the work of using VR technology to build a virtual reality scene in the digital exhibition hall of Manchu ICH in Changbai Mountain. Lili Lu and Yijie Lu [55] analyzed the Shanghai intangible heritage "Shanghai Proverb", and developed a VR design of oral ICH from three levels: content, scene, and interaction. Bozzelli [56] proposed a virtual exhibition platform that extends the experience of cultural heritage by enhancing the semantics and perception of artworks and ancient artifacts and helps users to understand them through immersive and participatory interaction and stimulation strategies. Selmanovic [57] created a story line in the virtual exhibition through 360-degree VR videos to tell the story of the Mostar Bridge.

2.3. Development of VR Technology and Bamboo Weaving

With an increase in the application of VR technology in the field of cultural heritage, studies related to the development of bamboo weaving techniques combined with VR technology have begun to appear, but the applications are relatively few.

Libo Wan and Yanqin Jia [58] collected and organized the Daoming bamboo weaving patterns, digitally interpreted them, and built a 3D database of representative patterns using VR technology to assist the design and production of bamboo weaving products. Kaining Meng and Peixin An [59] et al. took Qingshen bamboo weaving as the research object, established a database and digital exhibition hall, designed four modules, and developed a visual interaction platform. Wenli Zhang and Qian Zou [60] used VR technology based on Unreal Engine 3 to build an online communication platform to remove the barriers of communication between craftsmen and customers in the traditional bamboo weaving industry. Le Duan [61] discussed the principles of VR display design for bamboo weaving from the perspective of user experience.

2.4. Summary

After the analysis of the existing research, it can be seen that digitization of ICH is moving toward diversification, but the operability characteristics of the traditional craftsmanship of ICH, including bamboo weaving, have not been well explored and displayed. In the field of bamboo weaving, the application of digital technology mostly exists in the role of protection, assisted design, and production, and in terms of display and diffusion, digital media is still the main method. Virtual reality technology has great potential in the development of bamboo weaving techniques and needs further research and application.

3. Development of Bamboo Weaving Virtual Experience System

3.1. The Adaptability of VR Technology for Bamboo Weaving Display

As the embodiment of the cohesion and vitality of the area where the ICH occurs, the "locality" needs to be carefully protected and presented to the users. Virtual reality technology can break through the limitation of time and space in the display of bamboo weaving, which can provide the audience with more multi-dimensional and multi-level

information to further shape an all-round, virtualized, and three-dimensional simulation world for users [62]. The created cultural space can avoid the isolated display of ICH and present the physical form and the digital information at the same time, making the users enter a specific cultural context with immersive feelings [63]. Such application of technology maintains the mutual relationship between bamboo weaving and its human and ecological environment to the greatest extent so as to protect the "locality" and "vividness" of the information.

Compared to the traditional media, virtual reality technology provides multiple sensory experiences, allowing the users to be placed in the world formed by the media so as to gain an immersive experience [64]. Its interactivity and imagination has improved the quality and effectiveness of modern display art design to some extent [65]. The cultural content of the bamboo weaving is objectively reproduced in the space, making the users observe, touch, and even listen to the bamboo weaving exhibits more closely, which enhances the communication between the users and ICH, making them feel the ICH "roundly".

Although ICH has its physical cattier, its cultural value is difficult to physically reproduce. Therefore, the experience of ICH is "dynamic" and needs to form a dynamic cultural field including inheritor, space, and time [66]. The virtual reality display turns the users from audience into participants so that they can be personally involved in the process of bamboo weaving crafts. At the same time, virtual reality scene contains more natural user interfaces [67], which enables the users to master the mode of interaction with bamboo weaving products at a low learning cost. Moreover, the operations similar to reality also deepen the users' understanding of bamboo weaving.

3.2. Bamboo Weaving Virtual Experience System

The bamboo weaving virtual experience system establishes an interactive 3D virtual scene based on VR technology. The bamboo display content is dissected from three levels (material level, interactive level, and spirit level) and interpreted into three parts (materialized content, functional experience, and atmosphere rendering) in a virtual reality environment. In order to provide and convey information to users concretely, the virtual experience system of bamboo weaving truly reproduces the real production and uses scenes of bamboo weaving crafts, where users can roam and interact. During the process of interaction, the users can feel the touch of objects, hear stereo, and obtain visual feedback, which helps them to reduce learning costs and enhance their sense of experience. This system helps users recognize and understand bamboo weaving skills, diffuse the cultural value of bamboo weaving, and promote its sustainable inheritance and development in the modern context.

3.3. Development Process

As for the application's development software, the Unreal Engine 4 is selected for its advantage in 3D animation and other interactive content. For the device to run the virtual reality application, the Oculus Quest 2 is chosen, considering the criteria of good usability and effective use of reliable display devices. Using the Oculus link to connect the computer to headset, the users can experience the whole system in the headset and interact with scenes in virtual space with touch controllers. The whole system construction flow is summarized in Figure 1.

The construction of this system is mainly divided into five major steps: material preparation, environment construction, script writing, UI interface production, and storage and release. The first regards the preparation of relevant materials using Photoshop to process the pictures and make texture maps, choosing 3ds Max and Rhino for 3D modeling to make relevant models and build scenes. To build the scene, we collected a large number of 3D models and made necessary modifications in 3ds Max and Rhino. These two software applications can be used to easily open these models and make adjustments. In the second phase, once all these 3D elements are collected, the VR application is implemented on Unreal Engine 4. As soon as the model material, lighting, and sound effects are set, the

scene is rendered to build a virtual environment. Then, the blueprint is entered and the script is edited to set the interaction logic so that users can freely roam in the environment and interact with the items. This step is relying on the C++ language. Next, the UI interface is added to the system. Finally, after repeatedly adjusting the VR application, the entire virtual experience system is completed.

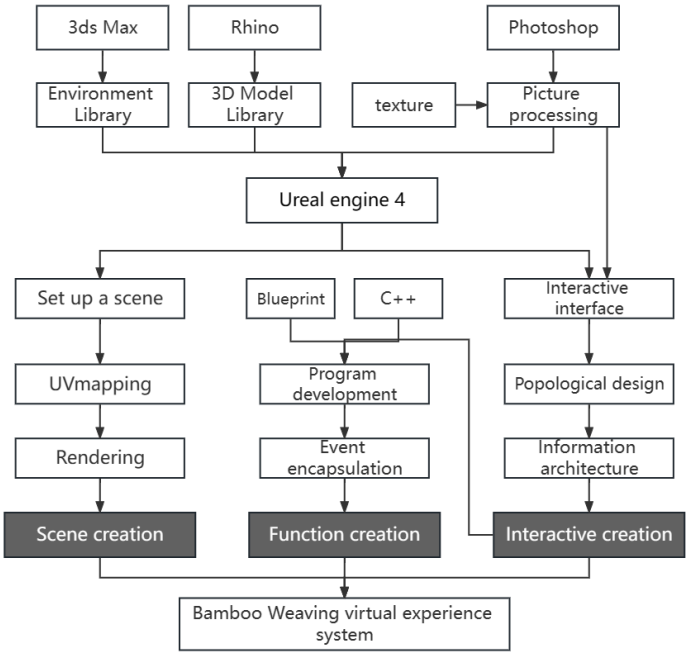


Figure 1. Development process of system.

3.4. Interaction Design

3.4.1. Interactive Elements

The interaction elements include bamboo weaving products, bamboo splits, etc. The color, shape, scale, and material of all models are basically the same as the real objects in physical scenes. They can all be interacted with by clicking and touching the laser beam, which shows good authenticity and interactivity. The information output forms of virtual reality system are various. For example, the laser beam can realize picking up and putting down the bamboo products, the magnifying glass can enlarge the details of the exhibits in the distance, etc. The information output form of the virtual reality system is diverse. On the basis of ensuring smooth interaction, clear perspective, and operability [68], there are various forms of interaction with users.

3.4.2. Interactive Mode

The bamboo weaving virtual experience system uses Oculus Quest 2 as the terminal device, which is equipped with a spatial positioning system that tracks the free movement of the user in a specific area. The virtual system is based on the device to design the user's interaction mode, which makes the users' interaction in the virtual world closer to their behavior in the physical world. The system adopts the interaction mode of combination of touch controllers and spatial positioning to simulate natural human behavior as closely as possible.

3.4.3. Interactive Logic

The interaction between the users and bamboo weaving products is the main way to understand the culture of bamboo weaving. In this bamboo weaving virtual experience system, four interaction methods are designed, including holding and placing of bamboo weaving crafts, the introduction of bamboo weaving crafts, weaving of bamboo splits,

and the user's movement in the position. This research mainly uses two touch controllers for interactive design, and each controller includes a joystick, two buttons (X/Y for the left hand, A/B for the right hand), a trigger, a menu key, and a grip key; the trigger can manipulate and trigger the item, and the button can activate the menu.

Handling of bamboo weaving crafts: it is mainly recognized through the trigger and the grasp key; when close to the bamboo weaving crafts, the users can press the trigger, dragging left and right to pick up the items, and release the trigger to release them. The basic logic of picking and dragging is similar, mainly by adding triggers, to the level control model to identify the pickable and draggable models in the scene for interaction. Picking and dragging requires adding a node to the product model and canceling the gravity of the product to achieve the effect of simulation of picking.

Viewing information of product: first, the laser beam emitted by the controller is aimed at the chosen exhibits, and the information feedback of the exhibits appears in the space interface; second, the grip key is pressed to pause or continue playing the videos in the exhibition hall.

Weaving experience: first, the laser beam is used to aim at the left space interface, the rocker is used to select the color of the bamboo splits and adjust the thickness, and the grip key is held to obtain the bamboo splits; second, in the right space interface, the type of pattern is selected and then the weaving instructions are viewed. Then, the controllers are used to hold the bamboo splits to simulate the natural behavior of weaving using the up and down position of the bamboo splits to understand the relationship between the pick and pressure of weaving. Finally, the bamboo slips are placed and the touch controllers are used to hold the cross bamboo splits and thread them through, and the operation is repeated.

Movement of the position: the controller is manipulated to move freely in the virtual exhibition hall by transmitting the cursor to the next target position.

3.5. Auditory Design

The auditory channel is an important sensory channel in virtual reality design. Reasonable auditory design can improve the effect of virtual experience, such as creating environmental atmosphere, enhancing sense of immersion, and increasing the fun of experience. Auditory information does not appear alone generally but needs to be matched with other sensory channels. The matching degree of sensory channel information affects the sense of immersion of virtual experience directly. The choice of sound needs to fit the context, and reasonable sound can induce users to enter a deeper and more lasting emotional experience [69], mobilize users' emotions, better attract their attention, and enhance their sense of experience. The auditory design in the bamboo weaving virtual experience system is divided into three parts: background music, voice, and system sound effects.

3.5.1. Background Music

Background music can create a good atmosphere for the virtual system. Scenes in the bamboo weaving experience system require ancient rhymes, which can be created by traditional Chinese musical instruments such as the "Guzheng" and "Guqin". In the virtual experience, each area uses a unified style of background music, so that all areas are connected into a whole to enhance the overall atmosphere. The specific implementation is: appropriate music materials are selected and imported into the built virtual scene, and the playing mode is set to loop when it is triggered.

3.5.2. Speech Sound

As the most natural way of communication between people, language is an important part of natural interaction [70]. Speech is the voice that conveys content, guides the user, and creates atmosphere. The narration is incorporated in auto-roaming, scene interaction,

and imitation experience. The narration explains from the view of the third person, creating a storytelling context so that users can immerse themselves in it.

3.5.3. System Sound Effects

System sound effects mainly refer to the feedback sound given by the system during the user's operation, such as collision sounds, prompt sounds, warning sounds, etc. Reasonable and appropriate sound effects can increase the fun of interaction so that users can truly feel the interaction between themselves and the target. To avoid the user feeling abrupt in interaction, the system sound effects need to maintain a unified style with the background music. Due to the spatial characteristics of stereo sound effects in virtual reality, hearing and vision are perfectly combined, which gives hints and guidance to users to achieve a full range of immersion. In order to avoid interrupting and fragmenting the sense of immersion, the overall sound effects of the system are not too obvious to distract the user in the interaction process. During the process of interaction, the background music gently lingers in the users' ears, and the sound effects and voice play simultaneously with the users' interactive operations.

3.6. System Composition

The bamboo weaving virtual experience system consists of three parts: information display, scene roaming, and learning module (Figure 2). The information display part introduces bamboo weaving culture, historical background, and humanistic information to help users build a preliminary impression of bamboo weaving. The scene roaming part displays the bamboo weaving life scenes, integrating bamboo weaving crafts into daily life scenes, to enable users to experience the sustainable vitality of intangible cultural heritage. The learning module provides users with basic weaving methods, making users immerse themselves in learning bamboo weaving and further interested in its culture. This system interprets bamboo weaving culture from multiple perspectives, diffuses the cultural value of bamboo weaving to users, and provides support for the sustainable development of ICH.

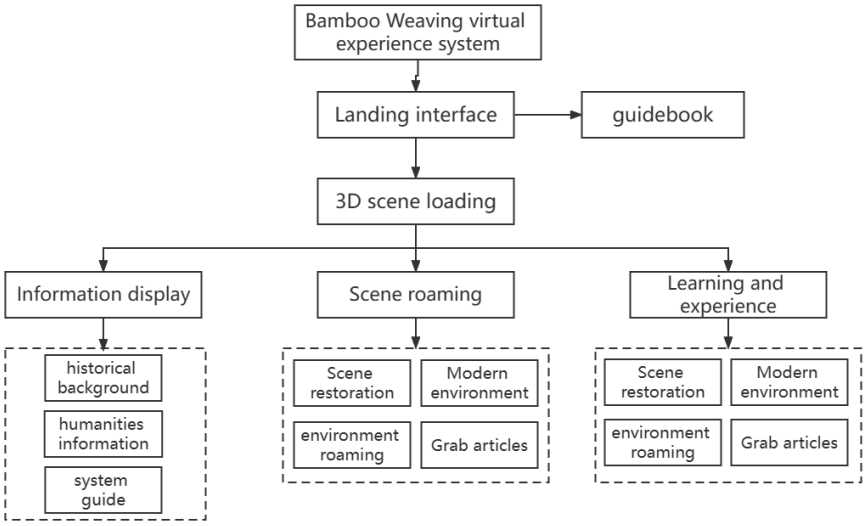


Figure 2. System structure.

3.6.1. Information Display

As an important embodiment of the spirit of bamboo weaving, the historical and cultural display space of bamboo weaving makes the audience immersed in specific historical situations and contexts and quickly enter the role by introducing the origin of bamboo weaving. The display content presents the story of Dongyang bamboo weaving inheritors and the crafts through auditory and visual sense. Users can listen to historical stories in the virtual gallery and interact with the exhibits and other scene elements. In the process of

interaction, the suggestive images, text, and voice are fed back in real time to make users quickly understand the specific humanities information of bamboo weaving (Figure 3).

(**a**) (**b**)

Figure 3. History and culture display space of bamboo weaving. (**a**) Displaying the story of inheritors with the laser beam. (**b**) Users can check the specific information for bamboo weaving crafts by clicking it.

3.6.2. Roaming through Life Scenes

With the development of the times, the functions of bamboo weaving have gradually changed. In the virtual environment, users can experience the scenes of bamboo weaving in different periods through scene restoration and scene reproduction. Not only can users experience the scene of bamboo weaving as production and living utensils in the old days, but they can also feel the beauty of decoration and practicality of bamboo weaving in modern art. The changing external form and the unchanging cultural core of bamboo weaving are both presented in the scene. In the process of scene roaming, users can choose to automatically roam or to move freely, breaking through the restrictions of time and space. Immersion can be achieved by emotional resonance, which is inspired in connecting the development process of bamboo weaving with the changes in personal life (Figure 4).

(**a**) (**b**)

Figure 4. Bamboo weaving living area. (**a**) Crafts of bamboo weaving in modern living environment. (**b**) With the hover flag, users are reminded which items are viewable.

3.6.3. Learning Module

In this area, users can experience and learn the basic weaving techniques of the patterns. Combined with the characteristics of virtual reality environment, the bamboo weaving process is redesigned. The tedious material processing step is omitted, and the interesting weaving step is retained, which is easy to spread. Users can experience bamboo weaving in an immersive way in the virtual environment. They can adjust the size and color of the bamboo splits and then choose the basic patterns to enjoy the fun of weaving. At the same time, the environment provides a strong cultural atmosphere of bamboo weaving, which helps the users to better immerse in the interesting learning process (Figure 5).

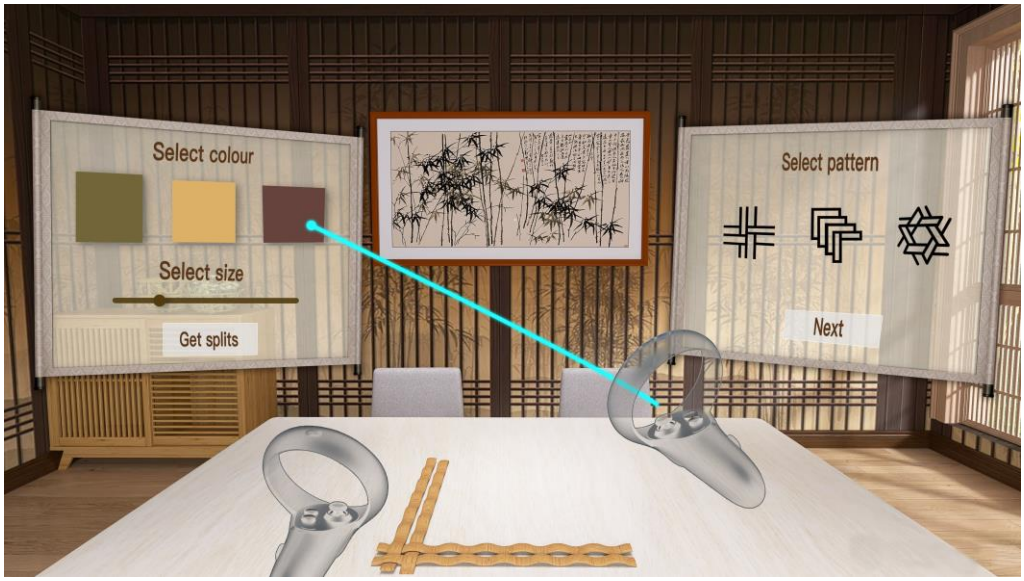


Figure 5. Learning area.

4. Evaluation Experiment

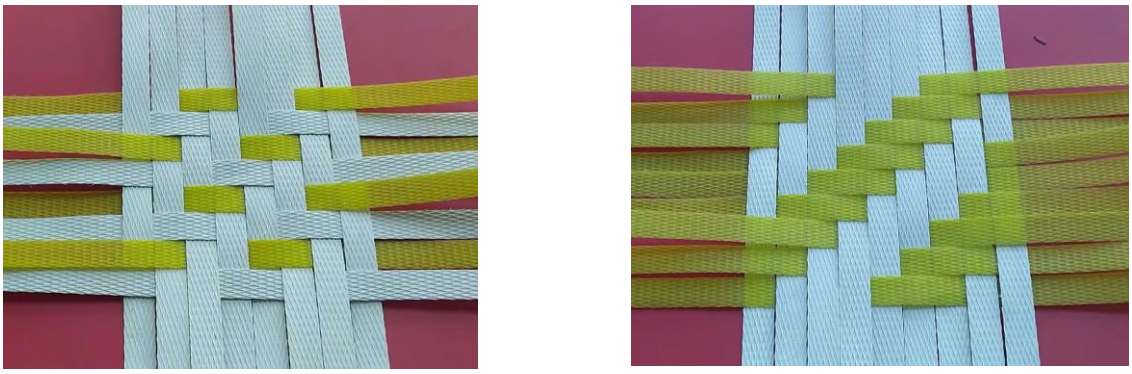
4.1. Purpose and Method

In the bamboo weaving virtual experience system, the learning module is the core of the system, giving users the opportunity to experience the bamboo weaving process. To test the effectiveness of the learning module, a comparative experiment is designed to explore whether there are differences in learning effect and experience between virtual reality system and computer screen. Comparing the duration and accuracy of the subjects' weaving under different learning methods, certain conclusions can be drawn. After the comparison, the subjects need to complete a questionnaire and a simple interview. In summary, this experiment evaluates the learning module from both objective and subjective aspects.

4.2. Subjects' Situation and Experimental Preparation

There are 8 subjects in the experiment, 4 males and 4 females, all graduate or undergraduate students from university. All of them are between 22 and 26 years old, with an average age of 24.7 years old. They have good ability of learning and understanding, and all of them have the experience of using VR devices before.

The Oculus Quest 2 is selected as the experimental device, and the system built in Unreal Engine 4 is imported into the device through the streaming line for the experiment. The herringbone pattern and twill pattern (Figure 6) are used as the examples in the experiment. They are all basic patterns of bamboo weaving, and the learning difficulty is moderate so as to avoid negative emotions in the experiment.



(**a**) (**b**)

Figure 6. Samples of pattens. (**a**) The herringbone pattern; (**b**) the twill pattern.

The experimental procedures are evaluated by experts and are free of ethical and moral issues. The content and process of the experiment are communicated when the subjects are recruited.

4.3. Experimental Process

After the subjects arrived at the laboratory, the researcher explained the general situation of the experiment for the subjects and informed them that their experimental data will be collected for research. After the subjects read the informed consent form, if there were no objections, they started the experiment after signing it.

There were 8 subjects in this experiment, and each subject was involved in two groups of experiments: Group A and Group B. The number of subjects in each group was 8. The two groups of experiments were separated by 1 day [71]. In Group A, the subjects used laptops to watch videos of bamboo weaving tutorials for learning; in Group B, the subjects used Oculus Quest 2 to learn weaving in the bamboo weaving virtual experience system. In Group B, the researcher explained the basic operation of VR glasses to the subjects before beginning. The learning time for both groups is 10 min, and the subjects had relative freedom during the learning period. In Group A, the subjects could speed up or pause the video during watching; in Group B, subjects were allowed to experience the weaving process repeatedly, but neither of the two groups could use physical objects for simulation. After learning, the subjects wove without assistance. The time they spent in weaving was counted. After they finished weaving, the patterns were individually numbered and photographed for recording. To avoid the effects caused by the cumulative learning experience, the two sets of experiments were conducted 1 day apart; on the interval days, subjects were forbidden from any other relevant forms of learning.

At the end of the experiment for both groups, subjects were asked to finish a questionnaire to rate their level of agreement with each statement. After submitted the questionnaire, the subjects were briefly interviewed about their feelings during the experiment.

To understand the subjective feelings brought by two different learning styles, the questionnaire starts from three dimensions: learning efficiency, emotional cognition, and system function. The questionnaire adopts the form of a Likert scale, with a score of 1–5, which from low to high indicates strongly disagree, disagree, indifferent, agree, and strongly agree. The questionnaire is shown in the Table 1. Questions 1–5 are about the computer side, and questions 6–10 are about the VR side. Subjects answer questions 1–5 after completing the test in Group A and answer questions 6–10 after completing the test in Group B. The subjects are mainly asked about their feelings about operation difficulty, learning difficulty, and learning interest.

Table 1. Questionnaire.

Group	No.	Question	Strongly Disagree	Disagree	Indifferent	Agree	Strongly Agree
A	Q1	I watch the tutorial clearly on the computer.					
	Q2	After the computer-side study time, I think I have mastered the skill.					
	Q3	It is convenient to watch the tutorial on the computer.					
	Q4	It is interesting to watch the tutorial on the computer.					
	Q5	After studying on the computer, I want to learn more about bamboo weaving.					
B	Q6	It is easy for me to learn in VR system.					
	Q7	I don't feel comfortable with the handle operation in VR.					
	Q8	Learning bamboo weaving in the VR system is interesting.					
	Q9	When learning in the VR system, I am attracted by the surrounding environment.					
	Q10	After the experience in VR, I want to learn more about bamboo weaving culture.					

After completing the questionnaire, the subjects were interviewed with the following questions:

(1) What impressed you most during the experiment? Describe it briefly.
(2) Did you encounter any difficulties or confusion during the experiment?
(3) Did you pay special attention to any part of the two different learning methods?
(4) Which learning methods do you prefer?
(5) What did you learn about bamboo weaving after the experiment?
(6) What did you learn about the traditional craftsmanship of intangible cultural heritage after the experiment?

The subjects' responses were recorded and summarized in a unified manner.

4.4. Results and Discussion

4.4.1. Experimental Data

The experimental data were collected and processed, which is divided into two parts. First, the evaluation of subjects' weaving results were judged from time and accuracy. Second, the subjective feelings of two learning methods were analyzed through questionnaires and interviews. Table 2 records the weaving time of the subjects in the two groups of experiments and calculates the average time spent in each group of experiments.

Table 2. Statistics of completion time.

Group	1	2	3	4	5	6	7	8	Average
A	432	398	478	405	447	483	513	357	439.13
B	336	342	411	381	359	401	399	326	369.38

Unit: second.

The weaving patterns of users were recorded and compared with the samples to recognize whether they are correct or not (Table 3).

The contents and result statistics of the questionnaire are shown in the Table 4. This table counts the highest score, lowest score, average score, and standard deviation of each question.

Table 3. Statistics of weaving pattern.

No.	1	2	3	4	5	6	7	8
Group A								
Group B								
Results	Group A is correct, Group B has one error.	Group A has one error, Group B is correct.	Group A is correct, Group B has one error.	Both Groups A and B are correct.	Group A has one error, Group B is correct.	The weaving order of Group A is wrong, and Group B is correct.	Both Groups A and B are correct.	The weaving order of Group A is wrong, and Group B is correct.

Table 4. Statistical results of questionnaire.

Group	No.	Min	Max	Average	S.D.
A	Q1	2	5	3.625	0.857
	Q2	1	5	3.000	1.323
	Q3	2	5	3.625	0.857
	Q4	1	4	2.375	0.857
	Q5	2	5	3.000	0.866
B	Q6	1	5	3.625	1.218
	Q7	1	5	2.375	1.218
	Q8	2	5	4.125	1.053
	Q9	2	5	3.750	0.968
	Q10	3	5	4.000	0.707

4.4.2. Discussion

From the statistical results in Table 2, it can be seen that in terms of completion time, the average in Groups A and B is 439.13 s and 369.38 s, respectively. The completion time in Group B is 15.88% less than Group A. Therefore, the average time to complete weaving in Group B is shorter than that in Group A. In addition, each subject takes less time in Group B than in Group A. Matched samples *t*-tests were used to verify the significance of the results. The result is calculated as t = 6.273, when $p < 0.05$, $t_{crit} = 2.365$, and since $t > t_{crit}$, it can be concluded that there are significant differences between the two groups. In terms of accuracy, there are four errors in the weaving pattern of Group A, two errors in Group B, and the error rate of Group B is 50% lower than that of Group A. According to Huiqin Zhao, Xin Zhang [72], and other scholars' research on theory of embodied cognition, the characteristics of virtual reality, such as immersion, interaction, and imagination, are conducive to the construction of embodied learning environment, which can effectively improve the learning effect. For this experiment, considering the two factors of completion time and accuracy, it can be seen that Group B achieves a higher accuracy rate in a relatively shorter time. That is to say, compared with the computer, using the VR system to learn bamboo weaving is more efficient.

For the Likert scale, questions 1, 3, and 6 focus on whether there are cognitive differences for subjects in the difficulty of the two learning methods. From the data results, there is no significant difference between the two groups, indicating that learning basic weaving, in the opinion of the subjects, is not difficult in both computer-side and virtual reality environments. Question 3 shows that most subjects think that learning on the computer side is still an easy and convenient way. This point is also proved in the following interviews.

The subjects indicate that the tutorials on the video sites are clear and easy to learn, but the VR system is "more fun" to learn. Q4 and Q8 ask the subjects how they feel about the two learning methods. It can be seen from the results that the subjects generally believe that learning in the virtual reality environment is more interesting. This is consistent with their narratives in the interviews.

For the most subjects, learning bamboo weaving through the VR system gives them a novel experience. Drigas [73] and others indicate in their research that the most important advantage of virtual reality is to enhance the sense of existence and improve the vividness of images, which develops positive visualization and brings expectation, hope, and optimism to the subjects. VR, as a new experiential medium, provides a different way of interaction from traditional methodologies. The scenes in the bamboo weaving experience system provide the subjects with an immersive space, so as to make them interested in bamboo weaving techniques. In comparison, this emotion is not evident to the subjects when they are learning on the computer side, which can be seen from the results of questions 4, 8, and 9. At the same time, most of the subjects indicate in the follow-up interview that they want to learn more about bamboo weaving skills. It can be seen that the bamboo weaving culture has indeed been diffused through this system, achieving the original intention of this study to encourage the sustainable development of bamboo weaving.

It is worth mentioning that some subjects say in the interview that they "thought they have learned it completely" after watching the tutorials on the computer side, but when they operate the splits on their own, they make mistakes; this problem does not occur in the VR system.

As to the use and operation of the touch controllers, because the interaction mode is different from the reality, some subjects have a slight maladjustment, but it did not reach the level that makes the subjects have negative emotions. In a study by Luxi Pan [74], it is shown that there is a difference in the user's perception of virtual space and real space. The spatial awareness formed in the real physical world should be expanded and continued in the virtual information interaction space, allowing people to interact naturally and thus gain a real sense of presence and immersion. Therefore, a more natural and reasonable interaction is the key issue to be considered when the optimization and iteration of the system are carried out afterwards.

The results of this study show that compared to traditional computer-based, learning bamboo weaving in a VR system is more efficient and better experienced, which is more likely to trigger users' interest and desire to explore bamboo weaving culture. At the same time, the virtual reality, as a new technology, brings some learning costs to the users. However, overall, virtual reality technology can help encourage the spread and extend the influence of bamboo weaving and bring positive feedback to the users. It provides new technical support for the diffusion and sustainable development of bamboo weaving.

5. Conclusions and Prospects

From the perspective of diffusion and experience, this paper discusses the feasibility of combining virtual reality technology with a bamboo weaving technique and builds a bamboo weaving virtual reality experience system based on the characteristics of bamboo weaving. Through comparative experiment, it is indicated that learning bamboo weaving in the virtual reality system is more efficient, has better experience, and can stimulate the positive emotions of the subjects, which verifies the effectiveness of the bamboo weaving virtual reality experience system. The characteristics of high immersion and strong experience of virtual reality technology help users better learn and appreciate the cultural value of bamboo weaving. Compared with traditional computer-based learning methods, VR technology helps to improve the experience and interest of bamboo weaving skills. VR technology can expand the scope of diffusion and provide new ideas for the sustainable development of bamboo weaving. In addition, there are limitations in this study, only learning modules were selected for evaluation. However, the diffusion and development of intangible cultural heritage, besides the skill, also includes many aspects such as its histori-

cal background and development process. This system should be expanded and evaluated from these aspects, which is also the direction of our following research. VR technology provides ideas for the development of bamboo weaving. In the future, this technology can be extended to other traditional craftsmanship practices of ICH such as paper cutting and embroidery, bringing more potential for the digital diffusion and sustainable development of ICH.

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