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# Teaching with virtual simulation: Is it helpful？

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# Teaching with Virtual Simulation: Is It Helpful?

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A growing number of construction-related virtual simulations demonstrate the benefits of providing students with a realistic and interactive learning experience to help them develop knowledge applicable to real-world situations. Virtual simulation provides a new form of teaching for physical experiments with high complexity, safety hazards, and excessive space. This study examined a course on the construction of Chinese traditional wood architecture for students majoring in architecture and related subjects. An experimental teaching platform with virtual simulation was utilized to respond to challenges of physical experiments. A questionnaire was administered to 74 undergraduate students and three teachers, and interviews were conducted with a subset of the participants. The results revealed that virtual simulation was helpful for students and teachers. This case study highlighted the potential of experimentation in the learning process through new technologies and reflected on whether the application of new technology was helpful to students majoring in architecture design.

Keywords: virtual simulation; Chinese traditional wood architecture; interactive learning; undergraduate curriculum

## Introduction

In recent years, significant growth has occurred in the development of special-purpose applications for education, including the implementation of virtual simulation (VS) and virtual reality (VR) (Hao et al., 2017). Prototypes and applications developed to date target various types of users, such as children, undergraduate students, postgraduate students, and students with cognitive or physical impairments, and cover a wide variety of training programs, such as pilot training, industrial production training, cognitive skills, and pedagogical targets, such as arts, study of historical sites, and development of real life skills.

Kavanagh et al. (2017) conducted a meta-analysis of 99 papers with various educational applications, and found that 51% were intended for implementation in higher education. VR and VS experiments can fully use the virtual space to simulate complex objects as well as ancient experimental operation methods, allowing students to learn easily and safely at low costs (Huang et al., 2020). As such, a growing number of universities are involved in creating virtual worlds for educational purposes (Zhao & Sun, 2017).

Internationally famous online virtual laboratories include the WebLab at the Massachusetts Institute of Technology, the virtual laboratory at Carnegie Mellon University, the virtual chemistry laboratory at Oxford University, the Material Science and Engineering Virtual Simulation Experimental Teaching Centre at Tsinghua University, the Chemical Engineering Virtual Simulation Experimental Teaching Centre at Tianjin University, and the Mechanical Virtual Simulation Experimental Teaching Centre at Tongji University (Zhao & Sun, 2017). With the gradually increasing maturity of applications in physics, chemistry, machinery, and other disciplines, architectural education has also begun to implement VS technology.

The construction of Chinese traditional wood architecture (CCTWA) is a fundamental part of the undergraduate curriculum in architecture, landscape architecture, and related disciplines. In the regular teaching process of Chinese traditional architecture, wood structures are regarded as an important factor in space composition, and the analysis and study of wood structures is one of the main ways to explore the concept of space and layout (Hao et al., 2017). This focus helps students obtain an overview of Chinese traditional wood architecture and systematically learn fundamental theories (Wu Lei, 2019).

However, this course contains two major challenges:

1. Traditional teaching of the theoretical aspects of CCTWA focuses excessively on class lectures, with construction methods complex and difficult to understand from drawings (Chu et al., 2020).
2. Traditional teaching of the practical aspects of CCTWA is combined with hardware-based experiments that are restricted due to complexity, limitations, and safety.
    - Complexity – After the Song Dynasty, all dynasties stipulated the height and thickness of various wood materials in detail. It is difficult for students to fully understand the wide variety of timber-frame building components.
    - Limitations – Scale models were developed to preserve this culturally unique architectural technique by allowing student to learn through the process of assembly. Due to the limitations of the school site and the number of mock-ups, only a small number of models can be constructed.
    - Safety – The models are usually large, creating challenges for students' work with them and risking students' safety. Furthermore, wood is vulnerable to fire, creating difficulties for laboratory preservation.

*Figure 1. Complexity, limitations, and safety of a traditional CCTWA course.*

VS offers a way to overcome the disadvantages of traditional experiments. For instance, Ohio State University utilized VR for graphical simulation of the construction process of the Chinese Dougong (Hao et al., 2017). Texas Health and Science University and National Tsing Hua University conducted manual assembly/disassembly experiments using augmented reality for engineering students (Chu et al., 2020). Tongji University set up a "virtual construction of the Song Dynasty Baoguo Temple" in its school of architecture and urban planning, where the names of components and the building process of the Baoguo Temple were introduced to students through an online VS experiment (Zhao & Sun, 2017). Peking University Archaeological Virtual Simulation Experimental Teaching Centre digitally recorded and displayed cultural relics through VS technology. The Art Experimental Teaching Centre of Sichuan Normal University used VS to teach students how to make a mortise and tenon structure with tools.
However, in general, more effective methods of knowledge transfer and the presentation of wooden structures assembly are still lacking (Chu et al., 2020). Not many VS experiments were offered by architecture departments in Chinese universities, and the content of those that were available generally focused on a specific ancient building rather than the basic structure and construction process, which is difficult for beginners to understand.

## VS Experiment Project

VS technology could effectively address the challenges of traditional teaching. This study collaborated with a technology company to develop a VS platform for undergraduate students, aiming to demonstrate the potential of VS in aiding in the teaching of construction techniques. From a general perspective, the discipline of architecture is likely to benefit from technology in the education process. As such, the use of VS in CCTWA courses should not be regarded as a new approach. However, unlike other VS experiments, the present experiment was based on the basic shape and modulus of the Dougong in *Yingzao Fashi* from the Song Dynasty, which is the earliest officially published architectural structure book in China.

### Experiment Description

The experiment focused on the study of the Dougong structure. The main characteristic of ancient wooden buildings is the lack of nails, screws, and other hardware parts due to the use of the Dougong. In Chinese, the word "dougong" consists of two parts, "dou" and "gong," denoting the two basic elements of the dougong structure, where "dou" indicates the inverted cap used for support and "gong" refers to the bow-like block used for supporting the load (Hao et al., 2017). The Dougong structure is a compulsory basic knowledge for undergraduate students in almost all architectural colleges and universities in China.

The VS experiment contained three sections:

1. The basic knowledge section, which introduced the basic knowledge and architectural background of each wooden component in detail. Students could drag the monomer in the interface to examine and study from different angles in a 3D view.

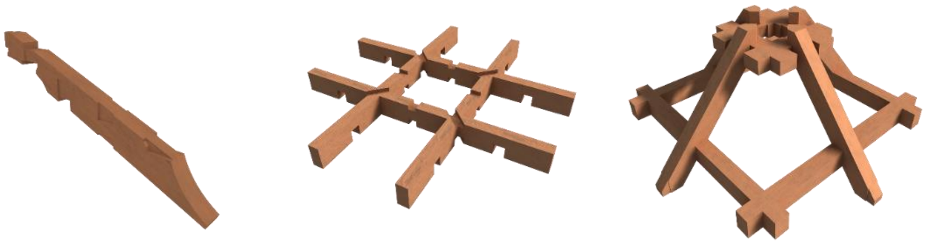

*Figure 2. Single part and combined parts of the wooden component.*

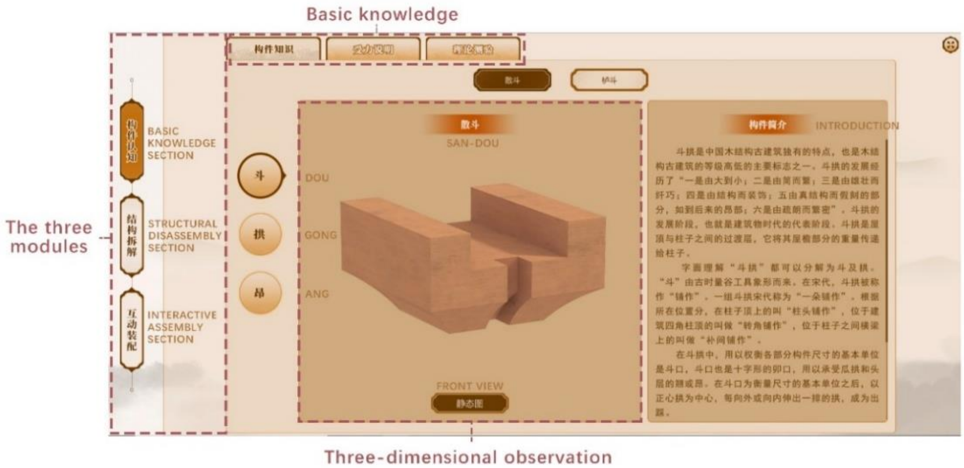


*Figure 3. Interface of the basic knowledge section.*

2. Structural disassembly section, where several typical wooden structures and detailed videos were displayed to help students fully understand the construction process.


*Figure 4. Interface of the structural disassembly section.*

3. Interactive assembly section, where students could choose single or combined wooden components

in the system, build wooden frames, and experience the assembly process of wooden structures in VS. The system calculated the time spent in the experiment and gave a score immediately after the experiment was completed.

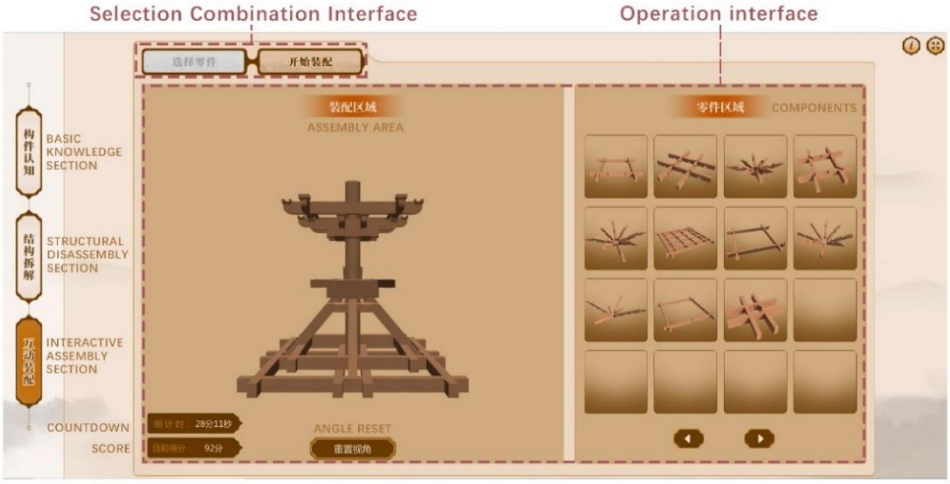


*Figure 5. Interface of the assembly section.*

The experiment was designed following game-based learning, where students had to complete assessments in each section before they could enter the next section. After completing the experiment, students had to complete a design assignment (small coffee bar or book-store) based on the newly acquired knowledge. Communication between instructor and students was conducted through email.

## Data Collection

74 students signed up after the information of the experiment recruitment was sent out. All participants were sophomores of the School of Architecture at Tianjin University with majors in architecture, landscape architecture, and urban and rural planning. The majority of the participants had little or no prior experience with VS. After the students completed the experiment, the teacher side of the experimental platform displayed the experimental time and score for each student. In addition, online questionnaire (including 5 questions about how they feel after the experience) were completed immediately after the experiment is completed in order to document students' first-hand impressions and feelings. With the commitment of privacy and confidentiality of participants, the written informed consents were obtained from all participants through emails. The experimental time and scores of students and non-students, as well as questionnaire results of the students were statistically analysed. In addition, 2 teachers and 2 teaching assistants were interviewed about reflections about this experiment after the teaching process.

## Results

A total of 74 students (41 men and 33 women) participated in the experiment and completed the questionnaire. The majority of participants (62.16%) rated the experiment as very interesting and satisfying (Fig. 5).

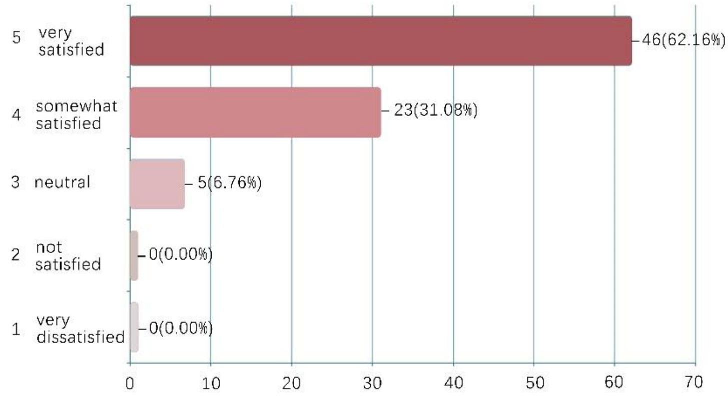


*Figure 6. How would you rate your experience with this VS experiment?*

In addition, compared with traditional wood structure experiments, most students thought that learning through VS was more rewarding (Fig. 6).

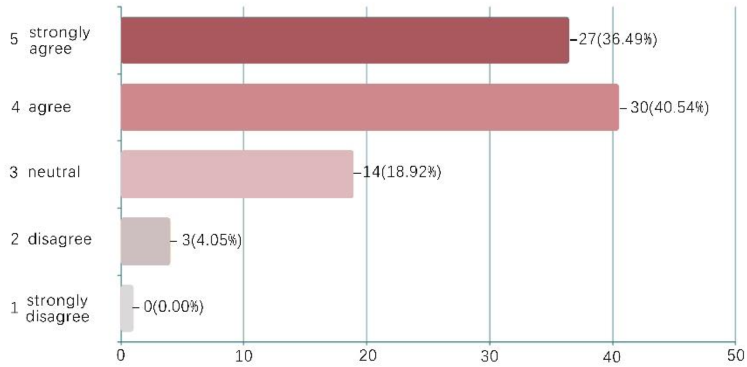


*Figure 7. Do you think learning Chinese ancient architecture through VS is rewarding?*

Less than half of the students (35.14%) reported little difficulty in getting used to the VS environment and completing the experiment, while more than half (64.87%) expressed some degrees of difficulties for the experiment (Fig. 7).

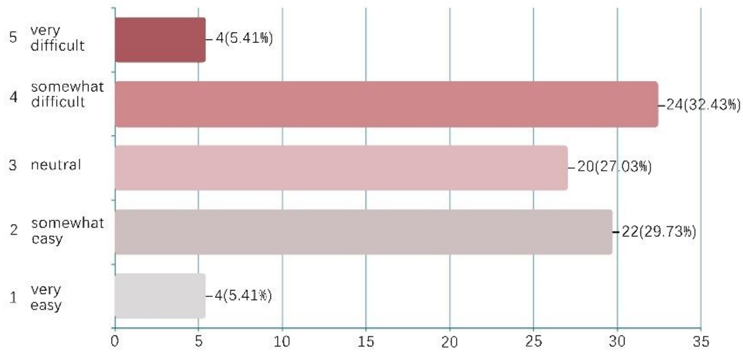


*Figure 8. How was your experience in terms of difficulty?*

When asked about the most interesting section, more than half of the students (58.11%) indicated the interactive assembly section (Fig. 8). This was the most creative part of the experiment. Students could choose components freely and assemble the Dougong structure. A total of eight experimental results could be assembled.

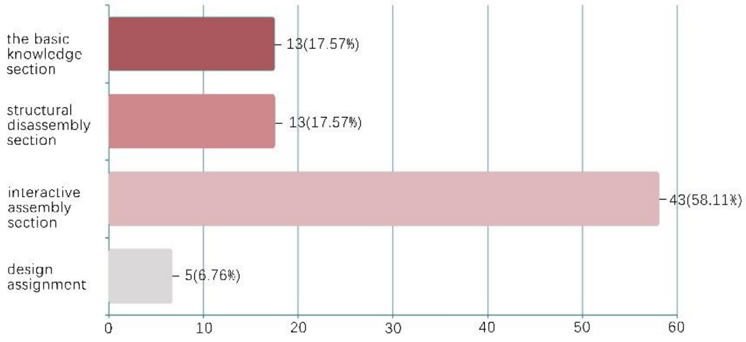


*Figure 9. What was the most interesting section?*

Although most students were satisfied with the experiment, they indicated necessity of improving all sections of the project (Fig. 9).

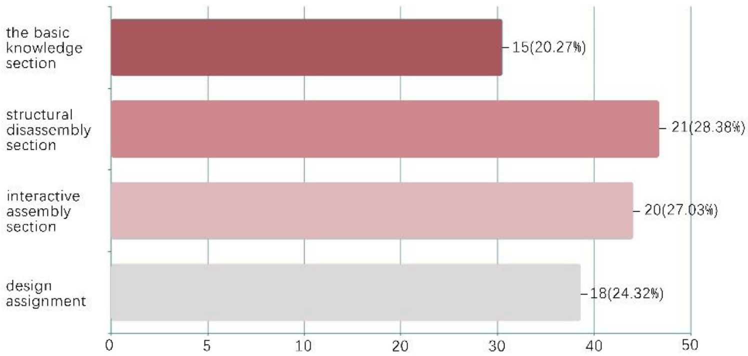


*Figure 10. Which section do you think should be firstly improved?*

This experiment was open to the public; therefore, people who were not students could also participate in the experiment. The experimental duration and scores of students and non-students were compared. There were no significant differences in scores between these groups, while students spent more time on the experiment (Fig. 10).

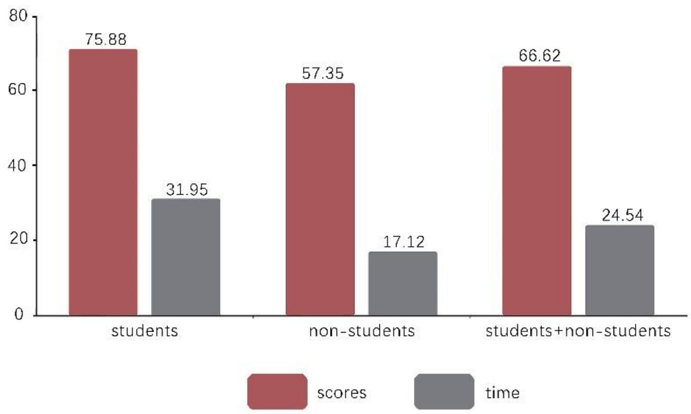


*Figure 11. Analysis of experimental data of students and non-students.*

## Discussion

This study aims to increase the overall student knowledge of Chinese ancient wooden architecture, and evaluate the acceptance and future possibilities of virtual technology in the field of architecture education. In addition to student questionnaires, this study conducted interviews with teachers.

### Students

According to the experiment results and feedback collected, students' satisfaction with this experiment was over 90%, while approximately 80% of the students thought this experiment was useful. The participants generally responded well to the experiment, thought it was novel and interesting, and acquired a further understanding of the wisdom of traditional Chinese wooden architecture, which was consistent with previous studies (Sun et al., 2010; Liang et al., 2019).

Students regarded the interactive assembly section as most interesting, indicating that students are eager to acquire knowledge actively in experiments. The traditional teaching of critical thinking can only rely on abstract methods, such as sketches and models. Due to a lack of technical means, large-scale tests and experiments cannot be conducted, and judgments continued to be based on experience (Wu Lei, 2019). However, diversified experimental results enable students to critically consider the best result within their own ability.

Furthermore, the participants suggested improving the interactive communication function of the experiment, in order to increase interaction and feedback during the experiment. As such, the participants considered real-time communication important. This should include communication between teachers and students, as well as among students.

### Teachers

The implementation complexity of this VS experiment project exceeded the teachers' expectation; however, the teaching effect was perceived as good, as it helped teachers address the inconveniences of real experiments, including reducing the experimental consumables expenditure, saving cost and space, and providing a safe controlled environment.

The VS experiment required teachers to devote more energy than traditional courses when compiling study guides and recording videos. In addition, it could track and provide feedback on practical teaching effects on students through time, which enabled teachers to improve teaching quality through self-reflection and teaching according to aptitude. Moreover, online learning provided access to high quality education at any time and from any location for both students and teachers. Therefore, this experiment was useful for situations such as the COVID-19pandemic.

### Limitations and Future Work

The experimental results of students and non-students were largely the same, indicating that the experiment was suitable for beginners. However, the scores of students and non-students were around the passing line, suggesting that the experiment did not fully account for differences in people's capacity. Future experiments should include assessments with difficulty gradients. For students with relatively high self-learning capacity, it is challenging to provide improvements matching their desire for new knowledge. As mentioned above, similar VS experiments were set up in several universities (Hao, et al, 2017; Zhao & Sun, 2017). Future projects should consider collaboration to allow students to participate in various types of experiments.

In addition, some students prefer in-person to digital learning (Kavanagh et al., 2017). Some students and teachers may be uncomfortable with the idea of engaging in or delivering a course entirely in a virtual classroom. As the goal of this experimental teaching was to cultivate students' practical skills, this experiment was a pre-course of practical operation, which could make up for the shortcomings of traditional experimental teaching, and provide more targeted coaching for future offline experiments.

## Conclusions

As both students and teachers considered the experiment helpful, teaching CCTWA with VS may provide a new path for the learning of architectural history and design. Experiments with potential safety hazards and challenging space requirements should utilize VS education. VS is an active teaching exploration, which could provide real interaction between students and teachers. It is hoped that this case study will spark a much-needed dialogue in the field of VS experiment teaching and promote discussion on effective applications of VS technology in the field of education.

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