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Research paper

Design and teaching application of a virtual simulation training system for bridge engineering drawing recognition based on Unity3D

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Abstract: In response to the common issues in practical training in vocational engineering construction courses, such as dangerous operation of training equipment, insufficient number of training equipment, and ineffective teaching, a vivid and interactive virtual simulation training system was developed using Unity3D software, taking the U-shaped bridge abutment in the course of Bridge Engineering as an example. Detailed introduction to the development and design process of 3D model establishment, ZSpace device adaptation, file format conversion, model rendering and disassembly, model zooming in and out, script writing and function implementation, UI interface design, etc., in order to achieve immersive interaction functions such as free observation, assembly disassembly, and ZSpace integrated VR virtual experience in the virtual simulation training system. The practical results show that the interactive effect simulated through the simulation training system is superior to that of the physical system, which can enhance the sense of experience, improve learning enthusiasm, and deepen the understanding of the knowledge points in Bridge Engineering Drawing Recognition. After the system is successfully established and applied in the training and teaching process, it will provide an important reference for the training and teaching of relevant courses for students majoring in road and bridge engineering, and also enhance the cultivation of high-quality skilled personnel in engineering majors in vocational colleges.

Keywords: engineering drawing recognition, Unity3D, U-shaped abutment, virtual reality, ZSpace

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1. Introduction

In 2020, the Vocational Education Department of the Ministry of Education of China issued a notice on the construction of a demonstration virtual simulation training base for vocational education. It pointed out that in the context of rapid development of information technology, there is an urgent need to build a virtual simulation training base. This is not only an innovation in traditional teaching, deepening the reform of talent cultivation mode, but also strengthening the integration of “virtual and real” education and teaching activities, effectively compensating for the low learning interest and insufficient equipment of students in practical training problems such as high risk are also addressed [1, 2]. More and more vocational colleges hope to enhance students’ interest in learning and improve the quality of practical teaching through the “integration of virtual and real” approach.

In the traditional “Bridge Engineering Drawing Recognition” course, most schools are accustomed to arranging students to attend classes in regular classrooms. Teachers use teaching and demonstration methods for teaching. During the practical teaching process, teachers release engineering drawings [3]. After students read them, they answer relevant questions or fill in relevant data. Students cannot deeply understand the three-dimensional geometry of the bridge, and the connection between various components, and students have low interest and initiative in the learning process [4, 5]. This traditional teaching mode is difficult to cultivate students’ innovation ability and comprehensive literacy, and there is a gap between it and the goal of cultivating high-end technical and skilled talents. The purpose of studying “Bridge Engineering Drawing Recognition” is actually to effectively understand and analyze the drawings of bridge engineering, so as to correctly interpret and apply relevant information in various stages such as design, construction, and maintenance. Therefore, the synchronous use of virtual simulation systems in the course of “Bridge Engineering Drawing Recognition” can enable students to more intuitively experience the transition from two-dimensional graphics to three-dimensional and spatial senses, effectively improving their learning enthusiasm and experience, and deepening their understanding of engineering construction.

Virtual simulation training teaching is an important measure to promote the integration of modern information technology into vocational education projects [6–8], and also an important means to cultivate innovative and composite technical and skilled talents in China [9–11]. Unity3D is a powerful cross platform game engine and development tool widely used in game development, virtual reality (VR), augmented reality (AR), interactive applications, and other fields [12]. In the context of bridge engineering construction knowledge, this article utilizes Unity3D software to organically combine complex U-shaped abutment model examples in bridge engineering with visual simulation teaching, transforming traditional teaching modes and cultivating students’ innovative abilities [13, 14].

2. Design scheme of virtual simulation training system for U-shaped abutment

Starting from the foundation of the practical teaching application of "Bridge Engineering Drawing Recognition", representative components, combinations, and knowledge points "U-shaped abutments" are selected as virtual simulation objects to develop a virtual simulation training system that has the characteristics of free observation, disassembly and movement, synchronous viewing from 3D model drawings to 2D structural drawings, beautiful and concise pages, and easy operation. It can be practical Effectively applied in the teaching of "Bridge Engineering Drawing Recognition" course. Fig. 1 shows the overall design scheme.

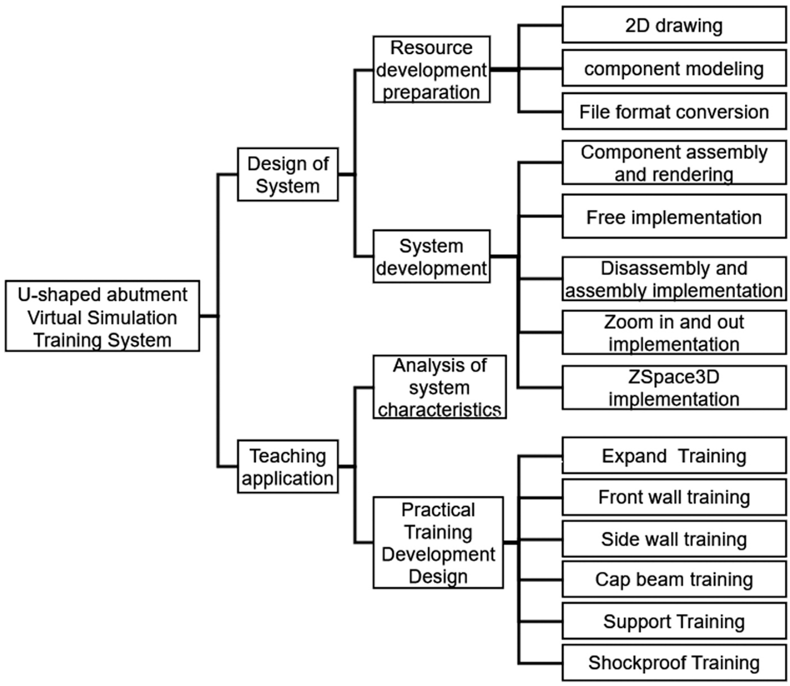


Fig. 1. Development plan for training system

3. Development of virtual simulation training system for "U-shaped abutments"

Export FBX format through modeling, drawing engineering drawings. Write interaction code using C# programming language, set parameters on the Unity3D parameter panel for interaction design, and finally export the software to the ZSpace desktop all-in-one machine. The development process of the virtual simulation training system is shown in Fig. 2.

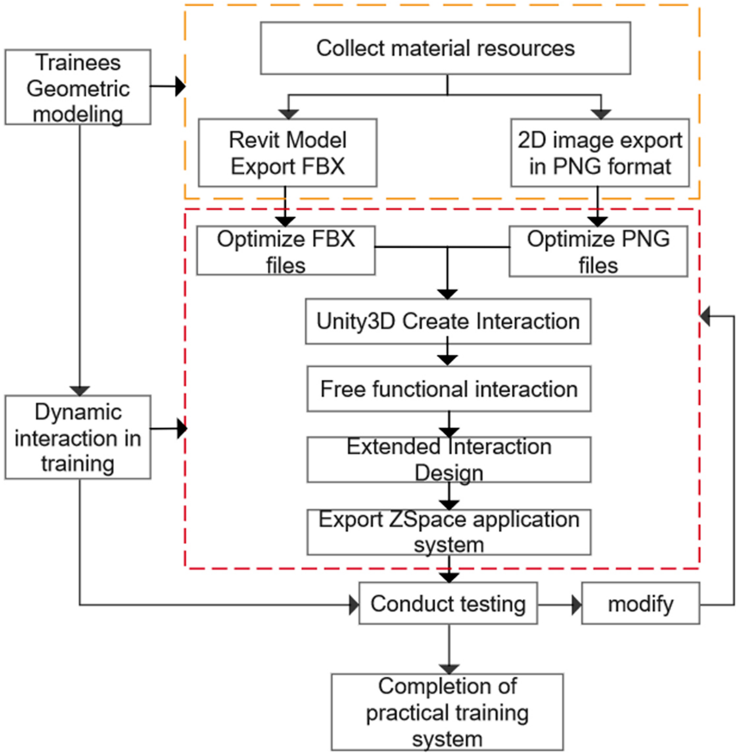


Fig. 2. Development process of training system

3.1. Model establishment and drawing of engineering drawings

By consulting materials, the component characteristics of the U-shaped abutment model were determined, and the commonly used BIM modeling software Revit was used to establish the model. The model diagram was in rvt format. Generate 2D engineering drawings from model drawings in Revit, and modify the overall and component drawing annotations, drawing names, and other details of U-shaped abutments through AutoCAD. The 2D engineering drawings are in dwg format.

3.2. Format conversion

In Unity software, files in rvt and dwg formats are not supported, while FBX and PNG format files can be used as the main import file formats for developing virtual simulation systems.

Use Revit to complete the 3D model, and directly select the FBX format file when exporting. Engineering drawings can be exported as 2D drawings in PNG format through screenshots.

3.3. Adjustment and rendering of model parts

The U-shaped abutment modeled and assembled using Revit has undergone FBX format conversion to form scattered components, and it is necessary to link and combine some of the same components. So, after importing the FBX model, it is necessary to reconstruct the parent-child element relationship of the same components, such as two support pads, two shockproof blocks, and two side walls, which need to be linked to parent-child elements before rendering in Unity3D. Fig. 3 shows the schematic diagram of the connection and assembly of U-shaped abutment components in Unity3D.

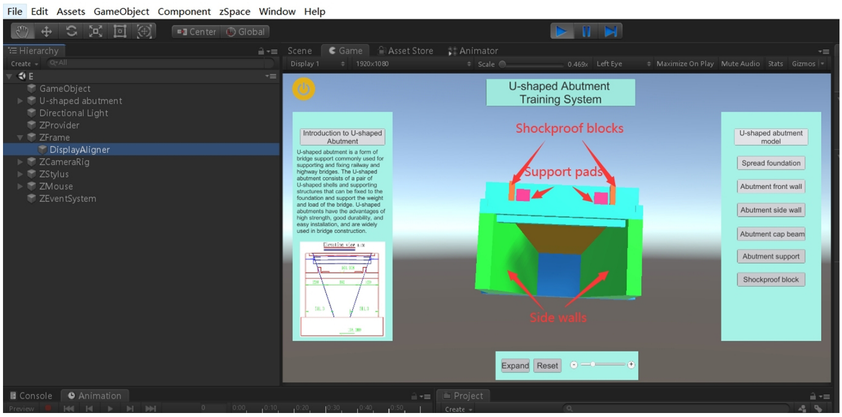


Fig. 3. Parent child entity reorganization

3.4. Free observation function

According to the basic functional requirements of the virtual simulation system, the ability to freely observe the entire bridge abutment and its components, control the camera's surrounding motion of the entire bridge abutment, and drag and drop of each component is called the free observation function. The script program that implements the free observation function mainly applies the content of the API and the knowledge of controlling camera activity.

Associate scripts with cameras and models to achieve free viewing function, determine that the model is the following target of the camera, complete the association, and achieve free functional observation.

3.5. Disassembly and assembly function

In order to better understand and observe the internal structure and combination method of U-shaped abutments, it is necessary to achieve the functions of disassembling and reassembling the combination, as well as displaying individual components separately, and the decomposed components should be clearly visible and not bonded. The effect that needs to be achieved is to divide the bridge abutment into 6 parts. When the corresponding component name button is clicked on a single machine, the component is separated from the overall model and the corresponding component introduction and 2D drawings are displayed. When the button is clicked again, the component is restored to the overall model. In addition, when the expand button is clicked, all six components explode and decompose, making it easier for students to view each component model. When the reset button is clicked, all components are combined into a whole.

3.5.1. Coordinate record before and after disassembly and assembly

The disassembly and assembly function can be achieved by recording component frame animations. Before recording the animation, determine the path and coordinates of the assembly's movement before and after disassembly, and record the coordinates of each part of the key frame's movement and component's movement.

For example, record the coordinate changes within 0–1.5 s before and after the disassembly and assembly of the shockproof block. Before moving, the component coordinates are $(0, 0, 0)$, and the component shock blocks inside the component are $(0, 0, 0)$; At 0.75 seconds, the coordinates of the component are $(-1.17, 3.05, -1.08)$, and at 1.5 seconds, the coordinates of the shockproof block inside the component are $(0, 0, 0)$, indicating that the motion is complete.

3.5.2. Animation recording

Recording the coordinates of the combination provides a prerequisite for recording animation. Recording animation refers to assigning two coordinates before and after the model based on time, and the model will move from the first coordinate to the second coordinate according to the set keyframe. Fig. 4 shows the animation effect of the shockproof block movement.

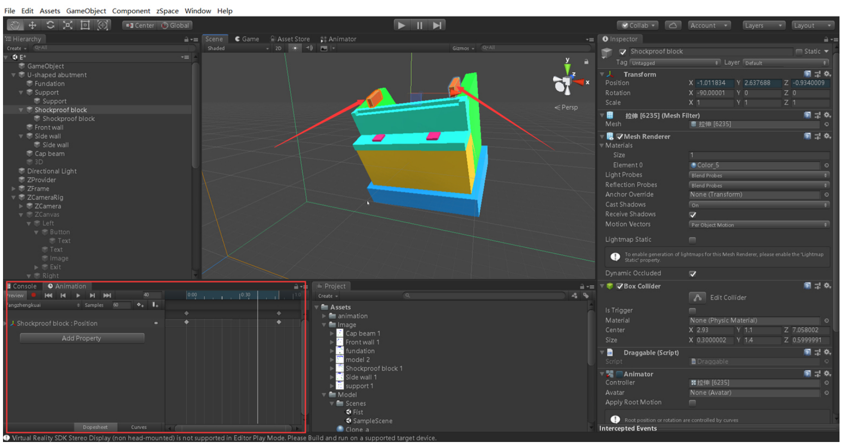


Fig. 4. Mobile animation effect

3.5.3. Animation playback logic settings

After recording the animation, it is necessary to rely on the animator components to logically set the animation to ensure the playback order. Logical sequence: There must be certain conditions before the animation can be played. Clicking on the corresponding component button triggers an event, and the returned animation must be played after disassembling the animation.

3.6. Zoom in/out function

During the viewing process, the model also needs to have the function of zooming in and out to facilitate the viewing of detailed construction. Set an image below the UI, insert a slider, and call the API in the code to achieve this; Then set the zoom in and zoom out buttons, add events for the overall model, and call the zoom in and zoom out API to achieve this.

3.7. ZSpace function adaptation

The ZSpace virtual reality VR all-in-one machine is a high-performance virtual reality device that can use 3D glasses and laser stylus to view the application model of the virtual world. This model on the device allows students to easily touch the built model, and the laser stylus is used for virtual space decomposition, which can greatly improve students' understanding of complex structures and their interest in learning.

To adapt to this device, it is necessary to import the ZSpace device parameters at the beginning of the design. After developing unity based on the device parameters, it is necessary to set the event settings for the control pen and 3D glasses of the main components of ZSpace. The operation steps are shown in Fig. 5, and the event call API can be implemented.

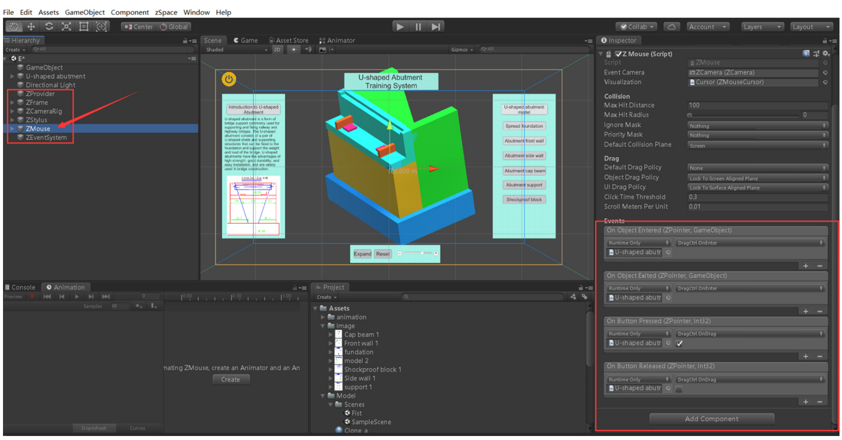


Fig. 5. Zspace control pen event addition

3.8. UI interface design

On the main interface, there are four canvases. The left side is the corresponding component introduction and drawing display area, the right side is the component button operation area, the upper part is the system name area, and the lower part is the disassembly and size function area. The main interface production effect is shown in Fig. 6.

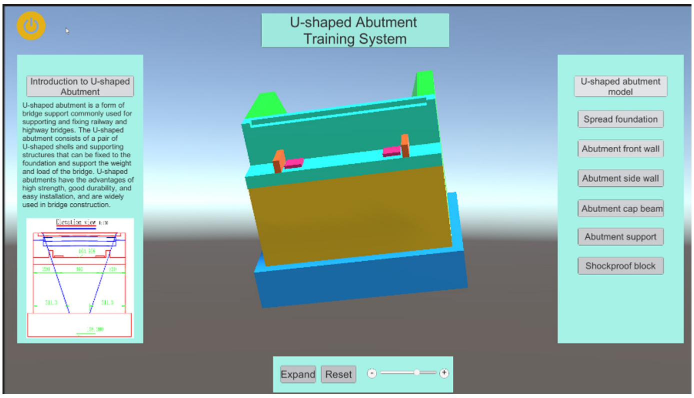


Fig. 6. Display of main interface production effect

4. Application of virtual simulation training system for 3 “U-shaped abutments'' in teaching”

The virtual simulation training system for “U-shaped abutment” based on Unity3D can help students learn basic knowledge of engineering drawing recognition, assembly disassembly, and engineering drawing. According to the training requirements of “Bridge Engineering Drawing Recognition”, develop practical training on bridge abutment structure and its engineering drawing and implement it in teaching. With the help of the ZSpace all-in-one virtual display device of the School of Urban Construction Engineering, the immersion feeling is enhanced to achieve more realistic simulation training. The display effect of the bridge abutment disassembly training is shown in Fig. 7.

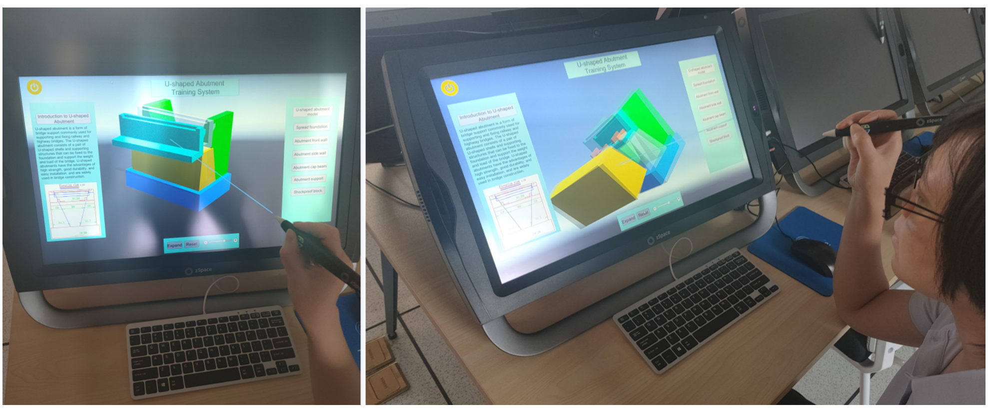


Fig. 7. Display effect of disassembly and assembly training on ZSpace all-in-one machine

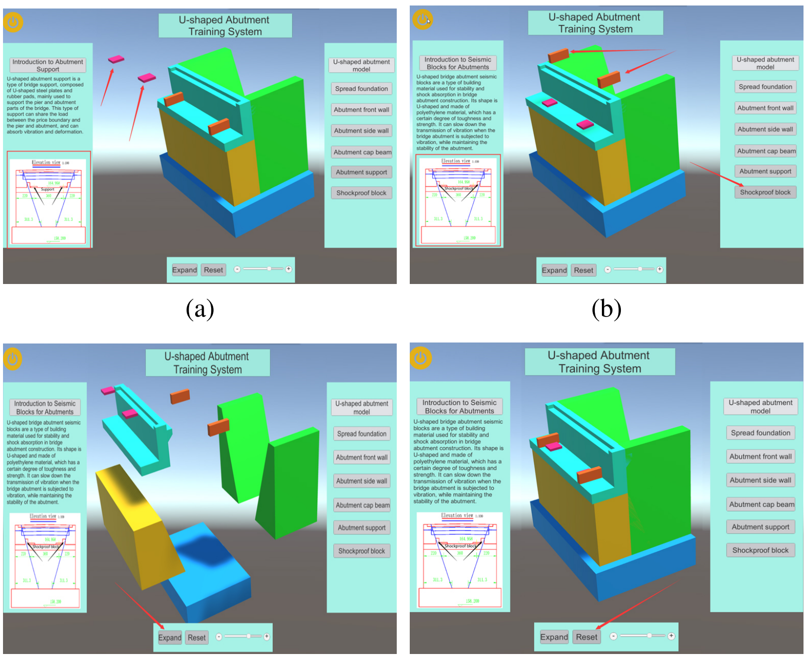
4.1. Practical teaching projects

4.1.1. Training objectives

Learn the structure of U-shaped abutments, understand the internal structure, component composition, and functions of the abutments, and enhance students' spatial imagination ability; Read the engineering drawings of the entire bridge abutment and its main components, understand the differences between the bridge abutment model drawing and the 2D engineering drawing, and enhance students' ability to apply engineering 2D drawings.

4.1.2. Practical training teaching content

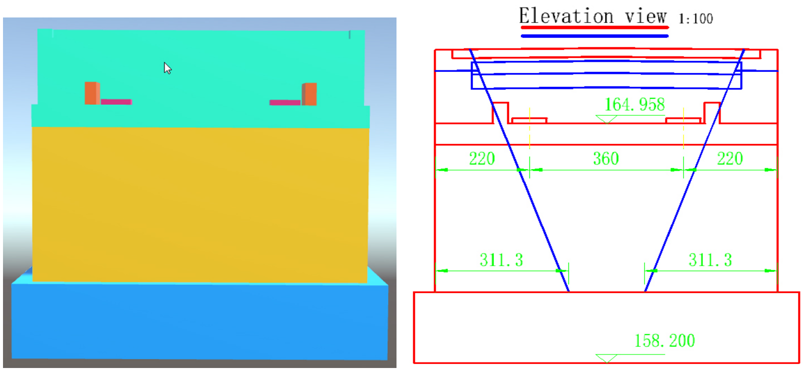
1. Students perform disassembly and assembly of bridge abutments
   Click on the disassembly and assembly process of the main components of the expanded foundation, front wall, side wall, cap beam, support pad, and shockproof block in sequence; Rotate and drag the components, observe and study the combination method of the internal structure of the bridge abutment, enhance students' curiosity and learning enthusiasm towards the bridge abutment structure, and deepen their understanding of the internal and external structure of the bridge abutment. Fig. 8 shows the process of students disassembling the bridge abutment.



(a) (b) (c) (d)

Fig. 8. Display of disassembly and assembly process; (a) Support pad disassembly, (b) Anti vibration block disassembly, (c) Expand All Components (d) Reset

2. Students can intuitively experience the similarities and differences between 3D models and 2D engineering drawings
   Students enter the bridge abutment operation interface. Firstly, the interface displays the completed model, and the left canvas displays an introduction to the U-shaped bridge abutment and 2D engineering drawing; Click on the corresponding component button on the right again to disassemble the model. The canvas on the left displays an introduction to the component, and a 2D drawing of the component is attached. This can strengthen students' understanding between 2D engineering drawings and 3D models, enhance their spatial imagination, and through this virtual simulation technology, students can "immerse themselves" in the "real" scene [15, 16]. Fig. 9 shows the comparison between the bridge abutment model and the 2D elevation.



(a) (b)

Fig. 9. Display of the model in unity; (a) Virtual model, (b) 2D engineering drawing

3. Group exploration to enhance spatial imagination ability
   Divide the students in the class into groups and work together in groups of four to conduct collaborative exercises. Have students carefully observe the 3D models and 2D engineering drawings of each component, and summarize and share them to enhance their spatial imagination.
4. Classroom exercises and homework assignments
   Disassemble the U-shaped abutment, find the position of the main components in the overall structure, and explain the role played by each component (teacher randomly asks questions). Able to independently separate each component and draw a schematic diagram of the component (teacher randomly asks questions).

4.2. Teaching effectiveness

In order to explore the application effect of virtual simulation training system in the course of "Bridge Engineering Drawing Recognition", Class 1 and Class 2 of Grade 21 Road and Bridge in Urban Construction College were selected for teaching practice, with a total of 95 junior college students. The comprehensive scores of the two classes in the previous academic year were basically the same, thus meeting the conditions for conducting this teaching practice. Class 1 of 21st Road Bridge is the control class (48 people), and Class 2 of 20th Road Bridge is the practice class (47 people). The control class implements traditional practical teaching, and the practice class adopts practical teaching combined with virtual simulation system. The two classes are taught for one semester. Table 1 shows the comparison table of practical training scores between the practice class and the control class.

Table 1. Training results of the practice class and the control class

Class	60–69 Points		70–79 Points		80–89 Points		90–99 Points	
	Nr of people	Percentage	Nr of people	Percentage	Nr of people	Percentage	Nr of people	Percentage
Reference class	18	37%	17	36%	9	19%	4	8%
Practice class	7	15%	12	25%	22	47%	6	13%

From the perspective of practical training results, the proportion of students in the control class with grades between 60 and 69 is 37%, while the proportion of students with grades between 80 and 89 is 19%. The proportion of students in the practical class with grades between 60–69 is 15%, and the proportion of students with grades between 80–89 is 47%. Therefore, applying the virtual simulation system to the practical training teaching of “Bridge Engineering Drawing Recognition” course in vocational colleges can effectively improve students’ learning effectiveness.

5. Conclusions

The virtual simulation training system in the course of “Bridge Engineering Drawing Recognition” breaks the traditional teaching mode of “teacher lecture” and “teacher demonstration, simple simulation for students”. By using the virtual simulation system, students can present a more intuitive learning situation. On the one hand, it is not only conducive to improving students’ learning interest and experience, allowing them to master knowledge through “playing”, but also helps to improve their spatial imagination ability, breaking through the limitations of low thinking ability, students can enhance their ability to recognize and draw complex engineering components through hands-on operations. Relying on the virtual simulation training platform to carry out practical teaching, the advantages and strengths of virtual simulation technology have been utilized, breaking the time and space limitations of traditional practical teaching, and effectively solving the problems of poor practical teaching effectiveness, insufficient equipment, and low interest and experience of students in classroom learning in vocational colleges. The practical teaching reform of engineering series courses is a long-term accumulation process, which needs to continuously optimize the virtual simulation system based on students’ learning characteristics, in order to promote the continuous improvement of teaching level and quality.

Acknowledgements

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