Design and Development of Digital Teaching Resources for HSE Training on Safety Management of Confined Space Operations Based on VR Technology

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Abstract. With the rapid development of technology, the application of virtual reality (VR) technology in the field of training has gradually received widespread attention. This study aims to explore the application of VR technology in HSE training for safety management of confined space operations, and improve the effectiveness and pertinence of training by designing and developing digital teaching resources. This article first provides an overview of the development process and future prospects of VR technology, and elaborates on the importance and challenges of safety management for confined space operations. Next, we will delve into the application scenarios and advantages of VR technology in HSE training for safety management of confined space operations, including practical safety training, scenario simulation, data collection and analysis, etc. Finally, this article proposes a design and development plan for a digital teaching resource for HSE training in confined space operation safety management based on VR technology, including hardware equipment, software tools, teaching content, teaching methods, and other aspects. The research results of this article indicate that VR technology has broad application prospects in HSE training for safety management of confined space operations, which can improve the pertinence and effectiveness of training.

Keywords: VR Technology, Confined Space, HSE Training.

1. Introduction

Virtual Reality (VR), also known as spiritual realm technology, is a new practical technology developed in the 20th century. Virtual reality technology encompasses computer, electronic information, and simulation technologies, utilizing computer simulation to create an immersive environment. At present, virtual reality technology is widely used in various fields of society, such as military, aerospace, architecture and industrial design, coal mining, chemical engineering, cultural and entertainment, and there are examples of achievements in the application of virtual reality technology. However, the current application of this technology in the field of HSE training in confined spaces of oil and gas field surface construction projects is not widespread, and there is a lack of exemplary typical cases[1]. Based on the characteristics of the industry, virtual reality technology is used to develop and generate HSE training projects in confined spaces on the basis of existing training and teaching. Innovative teaching interaction

IDEE 2023, November 24-26, Zhengzhou, People's Republic of China

DOI 10.4108/eai.24-11-2023.2343379

methods are used to provide participants with an immersive teaching experience, stimulate their learning interest, and enhance training effectiveness.

2. Analysis of the current situation of the combination of VR technology and HSE training research

In the HSE training of oil and gas field surface construction projects, practical training is an important link to improve students' safety awareness and skills. However, most of the practical training involved in this link is often unable to be completed through routine experiments and on-site physical operations due to the constraints and limitations of various working conditions such as large scale, multiple equipment, high cost, high safety risks, and enterprise production systems. With the rapid development of information technology, virtual simulation is an inevitable trend in the development of HSE training and teaching. The application of VR technology is an effective way to solve the practical teaching of HSE training for oil and gas field surface construction projects and avoid harsh environments, large scale, high investment, and high risks. How to utilize advanced information technology and modernization to improve the training quality and effectiveness of industry employees, and effectively enhance their safety quality, is an urgent need for HSE training business in oil and gas field surface construction projects[2].

With Southwest Oil and Gas Field Company fully embarking on a new journey of "producing 50 billion yuan", the task of surface construction projects in oil and gas fields has intensified, the risks of construction operations have increased, and safety management is facing severe challenges. The status of HSE training is becoming increasingly important. Whether it is required by laws and regulations or the safety production situation, HSE training is an important component of enterprise training and one of the important means to improve the quality of safety production work and ensure the sustainable and stable development of enterprises. However, the current effectiveness of HSE training for oil and gas field surface construction projects is not ideal, mainly relying on traditional teaching methods. This training method mainly has the following problems: firstly, the training content is simple and boring, students passively accept the training content, and the training effect is not ideal; Secondly, the training methods lack immersion and interactivity, making it difficult for students to vividly grasp the training points. For example, traditional teaching methods cannot present the structural principles of equipment and facilities, accident scene simulation, and other content intuitively and vividly; Thirdly, training is limited by production location, number of people, time, and other factors, resulting in low training efficiency[3].

2.1 Current Situation and Challenges of HSE Training on Safety Management of Confined Space Operations

Confined space refers to a closed, semi closed, or open space with potential hazards and safety risks, in which personnel need to enter for work, maintenance, or inspection activities. These spaces usually have the following characteristics: the space is relatively small and people cannot move freely; There is a certain degree of closure, such as pipelines, tanks, wells, pits, pools, etc; There may be hazardous factors such as toxic and harmful gases, flammable and explosive substances, oxygen deficiency, high temperature and pressure; Personnel entering confined spaces require special safety measures such as ventilation, testing, protective equipment, etc.

The current situation and challenges of HSE training for safety management of confined space operations are mainly reflected in the following aspects:

The training method is single: currently, most enterprises' confined space HSE training mainly focuses on traditional modes such as lectures. By focusing on safety education and training for all employees, it is not possible to comprehensively enhance their safety awareness; And there is less on-the-job training, and there is a lack of interaction in the training.

Lack of training responsibility subject: Lack of mechanism for cultivating "part-time trainers", failure to fully leverage the role of management and professionals at all levels in HSE training.

Poor training effectiveness: There is a lack of effective evaluation and tracking mechanisms for the HSE training effectiveness in confined spaces, resulting in less targeted training and difficulty in meeting the actual needs of enterprises and employees.

Lack of targeted training content: HSE training in confined spaces requires different safety requirements for job applicants, job approvers, and operators. However, existing training often only designs unified training plans from the perspective of HSE, without achieving personalized on-demand teaching during the training process.

2.2 Application and advantages of VR technology in training

The application of VR technology in HSE training in oil and gas field surface construction projects has the following advantages:

First, VR has the characteristic of immersion, which can make training vivid, intuitive, and visual. VR technology can provide students with a virtual environment that is completely consistent with the real environment. Like real scenes, it has vivid and intuitive characteristics, which can transform many abstract concepts, structural principles, or intuitive phenomena in front of students, making it easy for them to accept and understand. For example, a HAZOP analysis training on dehydration devices, relying solely on text and pictures to explain, will make students sound more difficult. If VR technology is used to simulate the structure, process, principles, etc. of dehydration devices, and presented to students intuitively and vividly, it can make students easier to understand and master[4].

Secondly, VR training is not limited by space, production, safety and other conditions. The advantage of VR training can be well applied in on-site emergency drills, high-risk operations, safe operation of new equipment, and new technologies in oil and gas field surface construction projects. For example, the drill on emergency response measures for oil and gas leaks at the production site is too risky and cannot be achieved if a real leakage environment is to be created on the actual site for conducting the drill. However, using VR technology, we can simulate leakage situations that cannot be achieved on-site, providing students with a realistic virtual environment. Students can achieve the best training effect by conducting exercises in such an immersive environment. It is also possible to adjust the status of unexpected events based on parameter settings and ensure absolute safety of the drilling environment.

Thirdly, VR training has strong interactive functions, timely feedback, and can be repeatedly practiced. Students can interact with all objects in the scene through human-computer interaction devices in a virtual environment with a realistic immersion and interactivity, experiencing real-time physical feedback, and conducting various experimental operations. For example, training on correctly wearing a positive pressure air respirator can be difficult for employees to practice repeatedly if physical training is used. However, through VR simulation operations, it is easy to practice repeatedly, and at the same time, it can timely understand whether the actions and steps are correct, which is beneficial for students to become proficient in actions and enhance memory.

Fourthly, VR training is safer, more comprehensive, and more economical. For example, conducting fire safety drills. Traditional drilling methods require the use of items such as smoke bombs and braziers, which increases the risk of drilling. If VR technology is used, fire, smoke, and even explosive environments can be presented very realistically. This makes the exercise environment safer, more comprehensive, and more economical.

3. Design and development of digital teaching resources for HSE training on safety management of confined space operations

Through preliminary research, it was found that safety training courseware developed based on VR technology currently on the market generally has issues such as lack of rigor in content, poor logic, weak scientificity, insufficient openness and practicality, resulting in VR courseware being unable to achieve training results and difficult to adapt to the needs of large-scale digital training[5].

This project aims to conduct innovative research on the deep integration of VR technology in HSE training for safety management of confined space operations in oil and gas field surface construction projects, establish a VR digital technology pedigree for confined space in HSE training of oil and gas field surface construction projects, and form guidelines for the design of a virtual simulation system for HSE training of oil and gas field surface construction projects based on VR technology, Build an efficient communication bridge between VR technology developers and trainers, improve the quality of VR training resources, and enhance training effectiveness. At the same time, it provides theoretical basis for the establishment of a virtual simulation training platform for HSE training and the development and implementation of VR training courseware in the next step, completes basic research for the promotion and application of VR training, and lays a solid foundation for the digital transformation of training.

3.1 Learner Analysis

The trainees of HSE training for oil and gas field surface construction projects are all adult learners with varying educational levels. They mainly have the following characteristics: clear goals, learning to balance benefits and costs, and giving and receiving[6]. Independent and independent, hoping to learn independently and think independently, rather than being indoctrinated. Experience learning, bringing in past experiences, with specific thinking and habits. Utilitarianism, only when aware of the necessity of learning can one be prepared to engage in learning and dislike being forced. Task driven, learning related to work tasks, and liking practical topics. Problem driven, enjoys solving real-world problems, and is willing to learn problem-solving ideas. These characteristics provide a fundamental basis for the development of VR teaching software[7].

3.2 Analysis of trainer's teaching needs

HSE trainers for oil and gas field surface construction projects generally lack interest and ability in virtual reality technology, which makes it difficult for trainers to apply virtual reality technology in the classroom, thereby limiting the students' exploration awareness and innovation ability, and also making it difficult for trainers to achieve the expected teaching objectives. From an objective perspective, HSE trainers for oil and gas field surface construction projects have not received systematic training on equipment usage, and there is a lack of available teaching equipment, resulting in a lack of hardware environment for teachers to use teaching facilities to implement teaching[8]. Therefore, traditional teaching methods can only be used for classes. From a subjective perspective, students lack the ability to apply and operate techniques in practice, which can reduce their interest in learning in the absence of practical experience. In addition, the overall HSE literacy also needs to be improved, as these issues all affect the overall teaching quality.

3.3 Teaching design principles and design ideas

3.3.1 Design principles

The design and organization of any educational activity is based on the theoretical foundations of education and psychology[9]. This study explores the design and development of VR teaching, focusing on the cognitive characteristics of adult learners in the specific operation stage and abstract logical thinking stage. It proposes that when designing VR course resources, students' physical and mental development characteristics and cognitive architecture should be considered to meet the psychological construction of adult learners. Specifically, we need to help students better understand the phenomena and principles in training and improve teaching effectiveness through simple, understandable, realistic, and interactive VR scenarios. In addition, in the development and design of VR course resources, it is necessary to follow the cognitive development laws of students, ensure that the interaction process conforms to their cognitive characteristics, and maintain the simplicity and comprehensibility of the interaction process. Ultimately, we hope to maximize the effectiveness of classroom teaching through effective human-computer interaction, allowing both trainers and students to participate in this process and achieve better educational outcomes. In the design and development of teaching software, the following principles should be followed:

(1) Principle of scientificity

According to the HSE training concept of oil and gas field surface construction projects, the scientific course should achieve the following five points: facing all students and based on the development of HSE literacy; Focus on core concepts and select course content; Scientific arrangement and advancement, forming an orderly structure; Stimulate learning motivation and strengthen practical exploration; Emphasize comprehensive evaluation and promote the development of students[10]. The design of this training should not only follow the students' thinking development characteristics, but also cultivate their core scientific literacy, so that they can have an understanding and understanding of scientific knowledge. Integrating VR courseware resources developed by virtual reality technology into the classroom is not only beneficial for achieving diversification of classroom subjects, but also for making teaching content more practical to homework, in order to cultivate students' HSE literacy, enhance their safety of homework operations and emergency response capabilities[11].

(2) Principle of openness

Teaching software combines classroom content with practical activities, and according to the characteristics of HSE training for oil and gas field surface construction projects, it should also have openness. The core concepts of various learning contents are interrelated, and the combination of core concepts of different learning contents together constitutes the architecture and system of scientific knowledge. Enable students to proactively identify and create problems during the learning process of this section, and engage in independent exploration and problem-solving.

(3) Challenging and competitive principles

Many of the HSE training for oil and gas field surface construction projects involve standardized content such as legal and regulatory requirements, operational norms, and operational procedures. So when designing, it is necessary to incorporate challenges and competitiveness. In the process of exploration and practice, students need to observe, think, and collect information themselves. These activities are also part of the students' growth process. Therefore, the challenging nature of science stimulates students' curiosity and exploration, prompting them to participate more actively in learning. The design of scientific teaching software should attach importance to exploration and practice, and increase students' choices of practical exploration to meet their psychological characteristics, thereby stimulating their learning interest and strengthening their attention.

(4) The principle of diversified teaching resources

Rich and colorful teaching resources are conducive to the conduct of teaching activities, and the rational use of teaching resources is conducive to stimulating students' interest in learning science, improving teaching quality. Diversification is a key principle for the rational utilization and development of curriculum resources. Diversified teaching resources have a positive promoting effect on the cultivation and development of students' core competencies, and are also conducive to professional development for trainers.

3.3.2 Teaching design ideas

This study conducts teaching organization and practice through the HSE training of oil and gas field surface construction projects, which involves entering the safety management section of confined space operations. A blended learning teaching model is adopted, and teaching design is redesigned based on content. VR teaching resources are developed using virtual reality technology, allowing students to internalize theoretical knowledge while completing exploration and practical activities, thereby improving teaching effectiveness. In the traditional teaching process of this section, multimedia teaching resources such as pictures and videos are used to present common confined space work accidents, related definitions of confined space work, safety risk analysis of confined space work, and technical safety requirements for confined space work through intuitive teaching methods. Teaching activities are carried out through classroom lectures. But teaching does not include practical processes, and students have a poor sense of experience, making it difficult for them to accurately learn relevant knowledge, skills, and emotions. This section of the teaching content uses virtual engine software to create virtual teaching resources for students to enter the virtual oil and gas field ground construction engineering operation environment through VR devices. Click on the set interface to complete answering questions, learning related operations, and determining hazard points. Utilizing practical exploration to help students gain a deeper understanding and mastery of knowledge points, as well as generate interest in working in confined spaces. It helps students to diverge their thinking, observe the details of homework independently, and understand the basic requirements of safety.

3.4 Analysis of teaching content

The safety management of confined space operations is a part of the professional HSE knowledge in the HSE training of oil and gas field surface construction projects, which requires management personnel, welders, plumbers, electricians, inspectors, and excavators to learn. The presentation is divided into four themes: common confined space work accidents, definitions related to confined space work, safety risk analysis of confined space work, and technical safety requirements for confined space work. The entire unit guides students to start with relevant cases, through which they can learn about common confined space operations accidents, familiarize themselves with the relevant definitions of confined space operations, conduct safety risk analysis of confined space operations based on the actual situation of the project, familiarize themselves with the technical safety requirements of confined space operations, comply with the safety technical requirements of confined space operations in project operations, and prevent accidents from occurring.

3.5 Teaching Objective Design

3.5.1 Knowledge and skill objectives

Understand the relevant terms and definitions of confined spaces, and be able to use these terms to describe related operations; Familiar with the various risks of working in confined spaces, and able to avoid these risks by adhering to work regulations; Familiarize oneself with the responsibilities and powers of one's profession in specific homework practice; Able to extract key management points for confined space operations in practical operations; Familiar with some typical cases of confined space operations.

3.5.2 Process and Method Objectives

Under the guidance of the trainer, through investigation and data review methods, various data can be used to analyze various risk points of confined space operations; Understand a specific confined space operation through experimental exploration, observation, and analysis and summary methods, and be able to express one's own observation results; By planning, organizing, expressing, and communicating, most oil and gas field surface construction projects are carried out for confined space operations, and the completed operations are summarized and summarized.

3.5.3 Emotional Attitude Values Goals

Driven by a sense of safety responsibility, adhere to relevant regulations and systems for confined space operations; Willing to use various ideas and methods to complete exploration, experience the joy of innovation, and improve and enhance the safety of homework; Understand the impact of standardized processes on practical operations.

3.6 Development of High Fidelity Models

High fidelity models are developed using Unreal Engine 5 (UE5), a real-time 3D engine developed by Epic Games and widely used in fields such as education, gaming, film and television, and architecture[12].

In science, engineering, and other fields, students need to use expensive equipment and materials for experiments. Using UE5 can create a virtual laboratory for students to conduct simulated experiments on a computer, thereby saving experimental costs and time. For example, NASA created a virtual laboratory called "Space Shuttle" using UE5, allowing students to simulate space missions and conduct related experiments. This project provides students with a practical opportunity and helps them better understand knowledge and technology in the aerospace field. Students at the University of California, Berkeley developed a game called "Bridge Constructor" using UE5, which aims to help students understand the structure and design of bridges. This project provides students with a practical opportunity and helps them better understand the process of game design and development. Students at the University of South Carolina have developed a virtual reality application called "Mars VR" using UE5, which aims to help students understand the geology and topography of Mars.

3.6.1 Design logic scheme

The software provides a comprehensive virtual reality learning platform, allowing users to immerse themselves in learning anytime, anywhere, and acquire the necessary skills and knowledge. Users need to enter the learning environment through a recommended browser, which includes modules such as virtual classrooms, virtual laboratories, exhibition halls, and real-life reproduction. These modules provide a rich interactive experience, allowing users to explore, move, and interact with other virtual objects in the virtual space. At the same time, users can also gain a deeper understanding of task scenarios through audio-visual demonstrations and complete assigned tasks. In addition, the software also provides various learning resources, including virtual models, presentations, video tutorials, and interactive questions, to meet the different learning needs of users[13].

During the learning process, users can engage in interaction and communication. This includes real-time communication with other learners, discussing issues, sharing ideas, and collaborating to complete tasks. This interactive learning method can enhance the learning experience and improve learning outcomes. After completing learning tasks or courses, users can continue to explore the virtual environment, discover new learning areas, and accept new challenges.

Evaluation and feedback are also important features of software. Users can adjust their learning plans and methods based on feedback by testing their knowledge and skill levels and receiving feedback on their performance. This evaluation and feedback mechanism helps users to timely understand their learning progress and ability level, thereby optimizing learning strategies and improving learning outcomes. The logical framework is shown in the following figure 1.

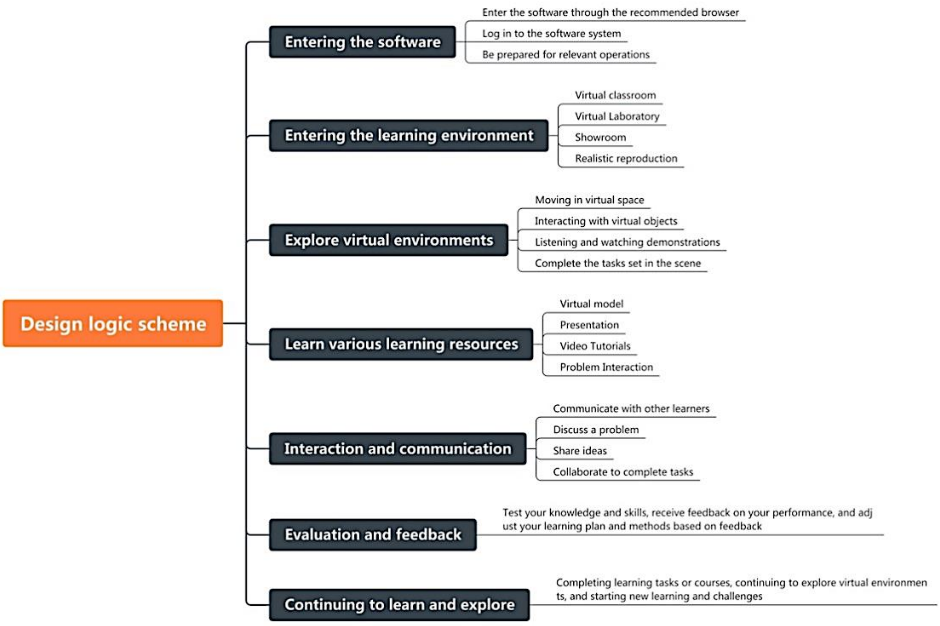

Fig. 1. Design logic scheme.

3.6.2 Implementation of the main interface module

The function of the main interface is to guide participants' operations, enter a confined space operation environment, and set a series of buttons. When roaming and learning in the scene, clicking these buttons in the appropriate area or time period can achieve corresponding functions. By using 3D modeling technology to reproduce the operating environment, learners can immerse themselves in the real learning environment.It is shown in the following figure 2.

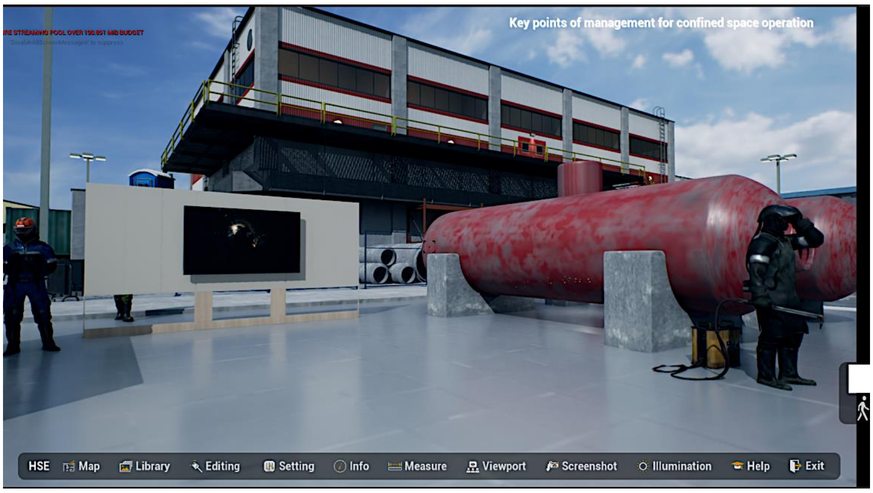

Fig. 2. Main interface diagram.

Firstly, import the main interface image resources into the project. In the "Control Blueprint" UMG, drag the image and button controls into the canvas panel, and add vertical box controls and expandable area controls to make the button UI layout neat, as shown in the following figure 3.

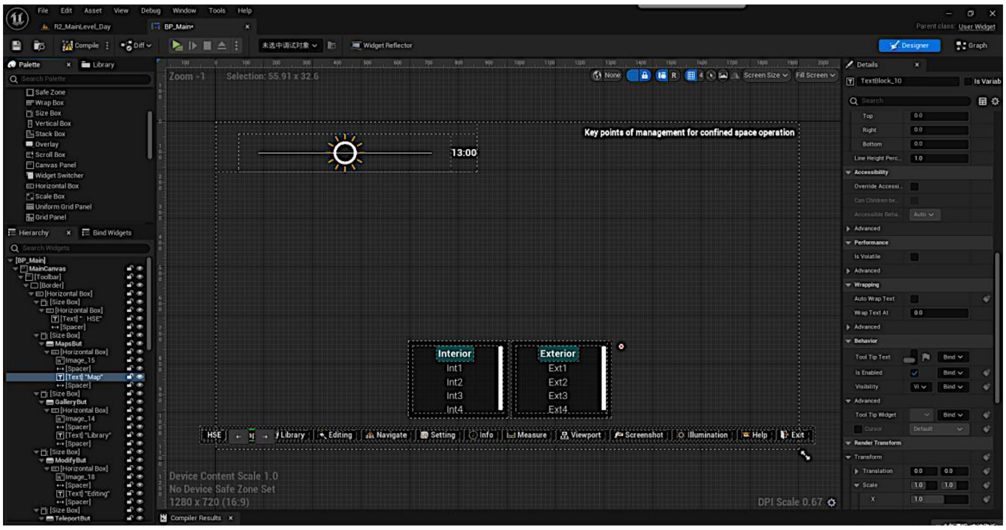

Fig. 3. Control blueprint import.

Now we will explain some button functions:

(1)The map button can display a brief scene map after clicking, making it convenient for learners to roam the scene without getting lost. The specific implementation blueprint is as follows figure 4:

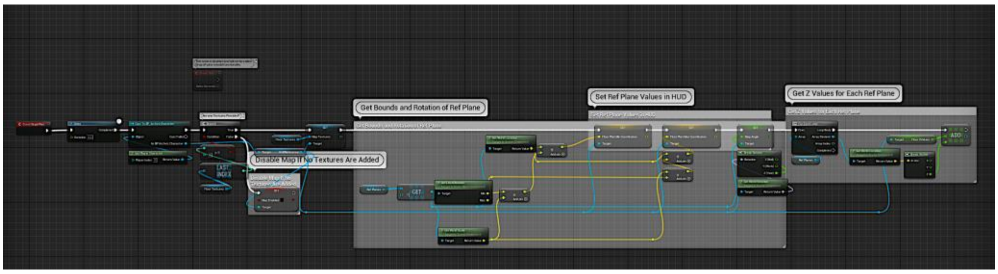

Fig. 4. Map blueprint.

(2)The image library button, after clicking, can bring up all the task maps or other related construction drawings, operation drawings, and other content that need to be completed in this lesson. It is a place for storing and calling media. The specific implementation blueprint is as follows figure 5:

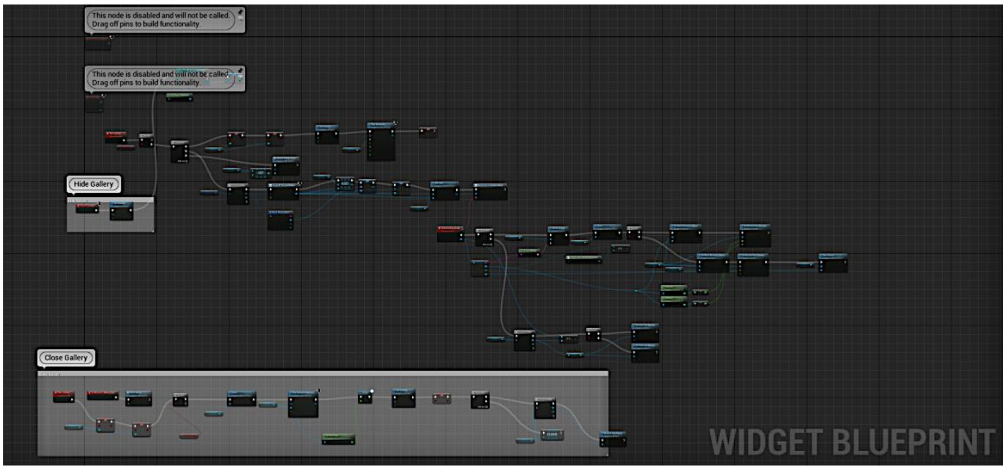

Fig. 5. Library blueprint.

(3)The edit button enables interactive operations on models with interactive buttons set in the scene, such as replacing materials, replacing replacement models, and various state change functions. The specific implementation blueprint is as follows figure 6:

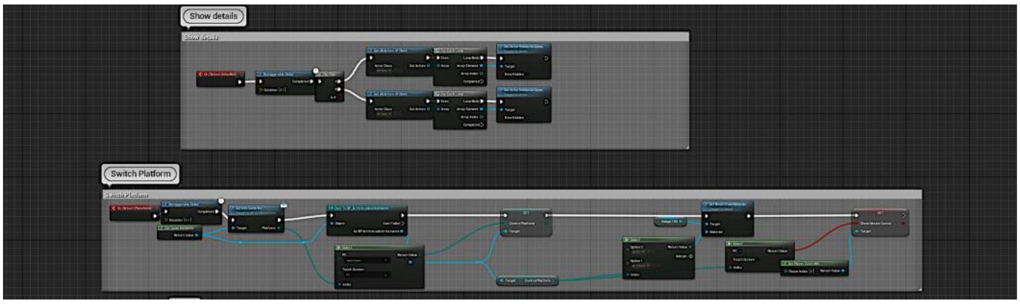

Fig. 6. Editing blueprint.

④ The setting button can be clicked to set the window size, resolution, visual effects, etc. of the entire courseware. The specific implementation blueprint is as follows figure 7:

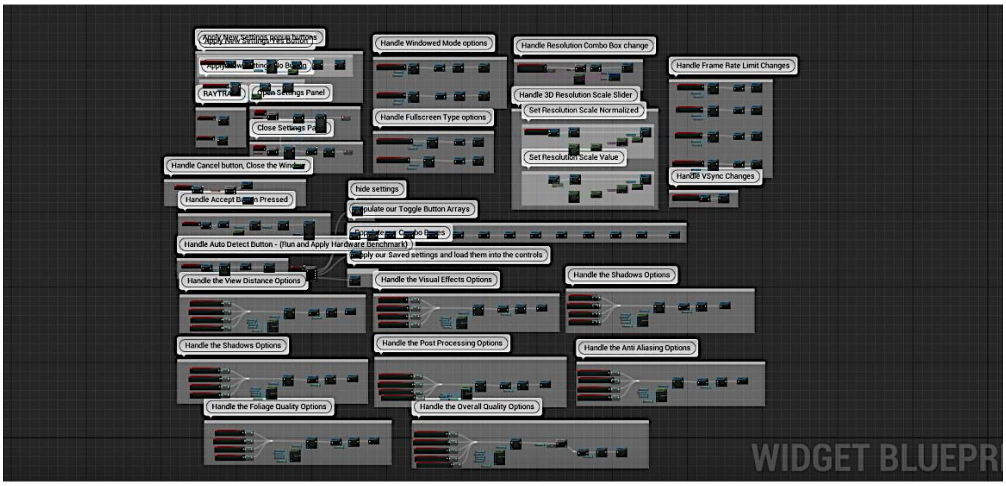

Fig. 7. Setting the blueprint.

⑤ The screenshot button allows you to save screenshots of the current window, making it convenient to save some important links. The specific implementation blueprint is as follows figure 8:

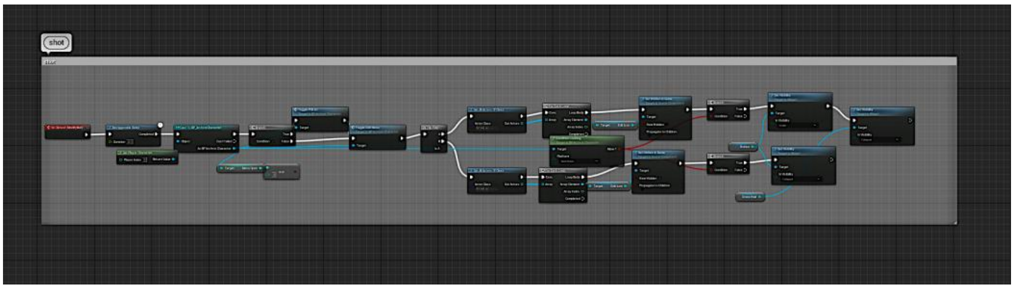

Fig. 8. Screenshot Blueprint.

3.6.3 Implementation of other learning functions

(1)Digital teaching resource display function: The teaching content is redesigned through multimedia digital teaching resources such as videos, pictures, and sounds. During the teaching process, relevant resources are displayed at appropriate times, which can play a good auxiliary role for learners. For example, in the section on management points of confined space homework, the first step is to provide learners with a rough understanding of the general situation of confined space homework, To lay a solid foundation for the next stage of practical operation learning. It is shown in the following figure 9.

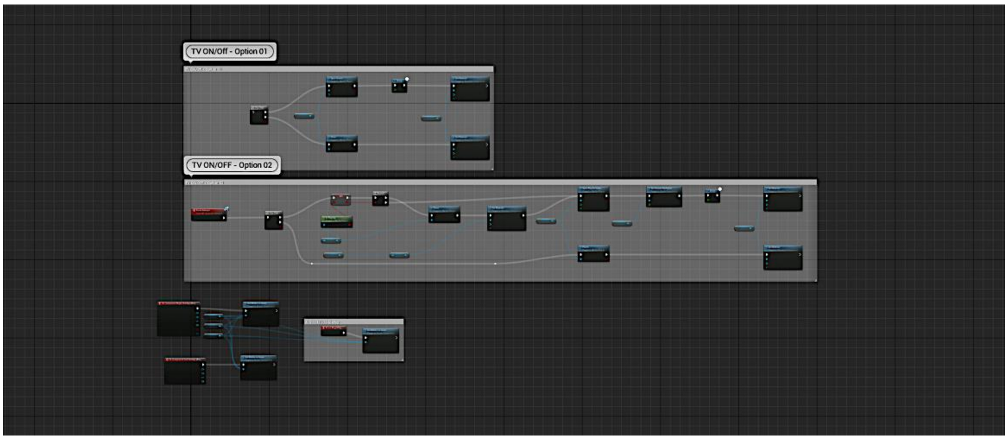

Fig.9. Design of the large screen interaction area.

(2) Online testing function: During the learning process, sometimes learners need to provide feedback on the learning content, which requires them to provide questions and choose options for interaction to elicit the learning content. It is shown in the following figure 10.

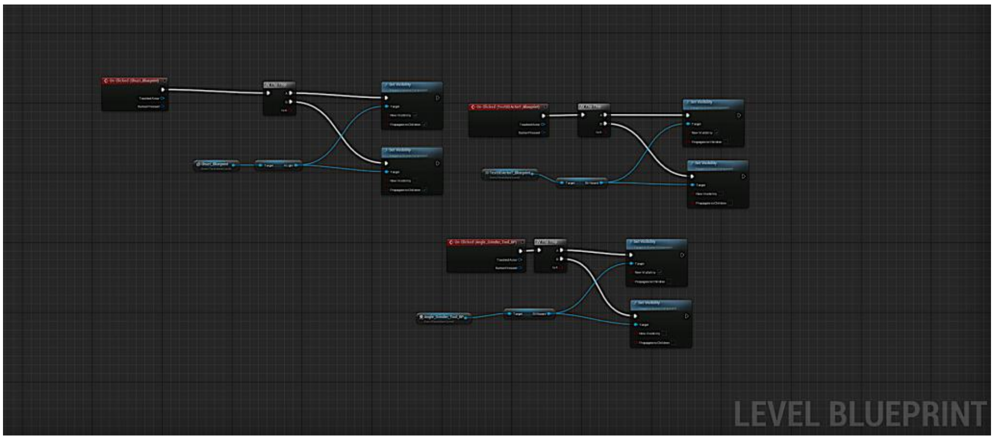

Fig. 10. Design of online testing area.

(3) Operational Practice Function

By reproducing the operation scenarios of confined spaces, students follow the requirements of confined space safety management to carry out relevant safety operation procedures, and truly experience the entire process of confined space safety management. Through practice, scenario reproduction strengthens the learning of this knowledge. It is shown in the following figure 11.

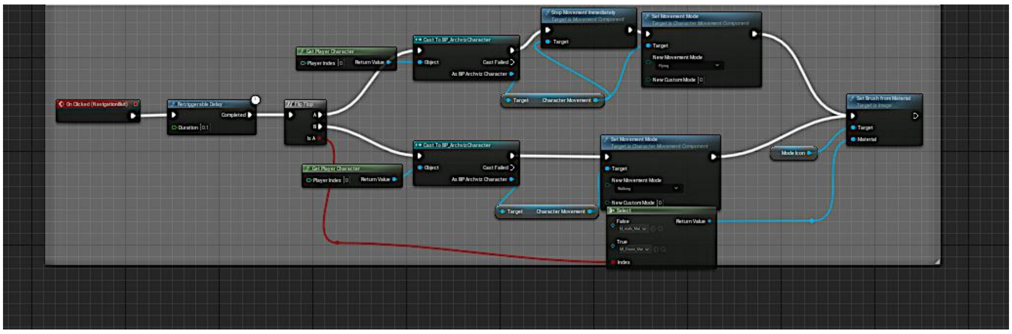

Fig. 11. Operational practice design.

The main interface module is the core part of the courseware, which implements a real confined space operating environment through 3D modeling technology. In the main interface, we have set up a series of buttons, including functions such as maps, libraries, editing, settings, and screenshots. By clicking these buttons, learners can roam and learn in the scene, conveniently view the scene map, retrieve task maps, and other related resources, interact with the model, and adjust the window size, resolution, and visual effects of the courseware. The courseware also provides other learning functions, such as digital teaching resource display, online testing, and practical operation functions. The digital teaching resource display function assists teaching through multimedia forms such as videos, images, and sounds, helping learners better understand the key points of confined space homework management. The online testing function provides feedback to learners during the learning process by providing questions and selecting options for interaction, leading to the introduction of learning content. The practical operation function allows students to perform practical operations in accordance with safety management requirements by reproducing confined space operation scenarios, thereby deepening their understanding and application of knowledge.

4. Conclusion

This article explores the design and development of digital teaching resources for HSE training on safety management of confined space operations based on VR technology. Firstly, the development history and future prospects of VR technology were introduced, and the importance and challenges of safety management for confined space operations were elaborated. Subsequently, the application scenarios and advantages of VR technology in HSE training for safety management of confined space operations were deeply explored, including practical safety training, scenario simulation, data collection and analysis, etc. Finally, a design and development plan for a digital teaching resource for HSE training on safety management of confined space operations based on VR technology was proposed. Research has shown that VR technology has broad application prospects in HSE training for safety management of confined space operations, which can improve the pertinence and effectiveness of training.

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