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Developing a VR Learning Environment for an Energy Sustainability Museum in Taiwan's Elementary Science and Technology Classes

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Abstract

This study aimed to address the lack of resources on energy sustainability in Taiwan's elementary Science and Technology curriculum by developing a VR learning environment, called the Energy Sustainability Museum, which was developed around the thematic concepts of energy and sustainability and can be visited and experienced through VR technology such as head-mounted displays or mobile VR as well as web browsers. The museum was designed to engage students in enhancing their knowledge and understanding of energy and sustainability concepts by integrating situated learning and operational learning through interactive and hands-on operations. The Energy Sustainability Museum is composed of three main areas: the energy introduction area covers thermal, hydroelectric, wind, nuclear, and solar power generation; the video tutorial area focuses on natural and renewable energy; and the gaming assessment area offers interactive learning and assessment on energy and sustainable environment topics. Together, these areas aim to provide students with a comprehensive and engaging learning experience. Overall, this study contributes to the field of energy education by providing a novel teaching and learning method for enhancing students' understanding of energy sustainability, which is critical for achieving the Sustainable Development Goals (SDGs). The Energy Sustainability Museum has the potential to support upper elementary classrooms and can provide a unique and interactive learning experience for students, allowing the related SDGs to take root in elementary curriculums.

Keywords: elementary science and technology, energy education, sustainability, virtual reality

1 Background and Purpose

In the post-pandemic digital era, incorporating information technology into instruction has become a daily trend. Through the use of virtual reality (VR), students can experience immersive learning beyond traditional human–human and human–computer interactions, enhancing their motivation to learn. With the diverse applications of digital learning in education, integrating VR into instruction through VR-based learning could improve the current learning methods.

In recent years, Taiwan has suffered from severe power shortages, resulting in frequent power outages and electricity rationing. The lack of energy stability and regional disparities in pollution sources have become critical issues, highlighted by the sudden island-wide blackout on August 15th, 2017 (i.e., 2017 Taiwan blackout), and severe winter air pollution in central and southern Taiwan. The most severe power outages occurred twice within five days in May 2021,

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affecting more than two million households. Due to its geographic location, Taiwan heavily relies on energy imports, and since electricity cannot be supported across national borders, improving energy self-sufficiency and diversification is crucial. As of 2021, Taiwan's power generation structure consists of coal (45%), natural gas (35.7%), nuclear power (11.24%), renewable energy (5.4%), hydroelectricity (1.13%), and oil (1.52%) [1].

In response to the United Nations' 17 Sustainable Development Goals (SDGs), Taiwan Power Company [2] has developed a sustainable development plan in its 2021 Sustainability Report, aiming to become a provider of sustainable electricity and focusing on SDG 3 (Good Health and Well-being), SDG 7 (Affordable and Clean Energy), and SDG 13 (Climate Action). The goal was to ensure that everyone has affordable, stable, sustainable, and modern energy, improve self-sufficient renewable energy to reduce energy supply risks during the COVID-19 pandemic, and expand zero-carbon energy development to improve power supply reliability under extreme weather conditions. This study aims to focus on the topic of energy sustainability and introduce it in detail through vivid and interactive VR-based learning, enabling the sustainable issue to take root and raise awareness of its importance among Taiwanese pupils.

1.1 Current Status of Energy Supply and Demand in Taiwan

Energy is the driving force behind a country's development and an indispensable element of its economic construction [3]. As the Taiwanese economy has developed rapidly, the demand for energy has consistently increased. From 2011 to 2020, the total electricity generation grew from 2,522 billion kWh to 2,801 billion kWh, with an average annual growth of nearly 2.8 billion kWh. The total electricity generation in 2020 increased by 2.09% compared to 2019, an increase of about 5.734 billion kWh. Among them, gas increased the most, by a total of 9.57%, while coal and oil decreased by 25.85%. Renewable energy generation decreased by 0.84%, and nuclear energy decreased by 2.73% [4]. Currently, Taiwan is limited by factors such as insufficient equipment and high costs for green energy, and cannot replace thermal power generation in the short term [3]. Taiwan's current electricity generation still relies mainly on coal, gas, and nuclear power, with a relatively low proportion of renewable energy, and it is not yet able to use green energy as its main source of electricity generation. Instead, it can only assist in reducing the overall carbon dioxide emissions. The use of green energy for electricity generation is also Taiwan's future goal, and it will be integrated into a large-scale power grid to provide stable electricity to the people.

1.2 Educational Applications of VR in Virtual Spaces

Virtual reality (VR) is the use of computer technology to create a three-dimensional simulated environment that offers users the sensation of experiencing it through various senses, such as sight and hearing, without any restrictions of time and space. By enabling users to observe and interact with the designed 3D space, VR has significant potential in science education, such as in the fields of atomic structure, astronomy or space science, and intricate architectural structures, where practical experiments are not feasible in a laboratory setting [5][6]. Moreover, teachers can use VR to involve students directly in the learning process, encouraging their active participation and facilitating discussions and feedback in virtual space. This enables teachers to adjust their teaching content, pace, and methodology based on the students' learning progress and feedback [7]. As Wang [8] has pointed out, using VR devices to interact with students in a virtual space can significantly enhance learning efficiency and interaction experience in the classroom.

As analyzed by Guo [9], using virtual space as teaching material for experimental courses and guiding students in operational experiments under the teacher's guidance can effectively improve learning outcomes. Using virtual worlds for teaching is a trend for the future; for example, students can be trained to face rare and high-risk clinical situations, thereby bridging the gap between the classroom and practical applications and improving the smoothness of the process from novice to expert [10][11]. Through simulated scenarios in VR, students can acquire professional knowledge and enhance their learning motivation through situated learning. Meanwhile, situational simulations can also cultivate students' ability for independent thinking and problem-solving, thereby improving their practical performance [12]. As such, situated learning through VR could help students concentrate more on learning.

1.3 Research Purpose

The curriculum of "Science and Technology" for elementary school students in Taiwan covers content related to energy sustainability; however, it is only briefly introduced and lacks in-depth coverage. Therefore, the purpose of this study was to deepen and broaden the topics related to energy sustainability by employing situated learning and operational learning in a VR learning environment called the Energy Sustainability Museum, which displays these topics and simulates various types of power plant scenes, allowing students to experience this immersive learning environment and interact with the surroundings through interactive and hands-on operations. By incorporating this VR learning environment, the ultimate goal is to improve the current teaching approach and allow the SDGs to take root in the elementary Science and Technology curriculum.

2 Learning Environment Development

2.1 Platform and Applicable Devices

This study utilized the CoSpaces Edu application to create a VR learning environment for energy sustainability, suitable for upper grades in elementary school's Science and Technology curriculum. CoSpaces Edu can be experienced through a computer, mobile device, or VR/AR headset. This learning environment can be operated and experienced either through a web browser on a computer or via the CoSpaces Edu app on a mobile device. It can also be experienced with VR devices (such as VR headsets or mobile VR devices like Google Cardboard).

For computer operation, use the keyboard keys (WASD or ↑←↓→) to move up, down, left, and right, the space bar to jump, and left-click to trigger events and rotate the camera view by dragging. For mobile phone operation, the screen's left side (↑↓) is forward and backward, and the right side (↑) is jumping; dragging the screen changes the camera angle and direction, and clicking the screen triggers events. For mobile VR operation, the camera angle is changed by body movement; short press the right button to trigger an event, and long press to move forward.

2.2 Content and Target Audience

The target audience is upper elementary school students. The content is the learning area of "Science and Technology" in 6th grade second semester, including (1) Han Lin (翰林) textbook: "Resource Development and Sustainable Management" in Chapter 4 of Unit 3, (2) Kang Hsuan (康軒) textbook: "Cherishing Natural Resources" in the Activity 3 of Unit 3, and (3) Nan I (南一) textbook: "Caring for the Environment" in the Activity 3 of Unit 3.

2.3 Scene Conceptualization and Design

The Energy Sustainability Museum is designed for upper grade elementary school students to learn about energy and sustainability issues through VR scenario-based learning, operational learning, and interactive learning. This study utilized the built-in materials of CoSpaces Edu as well as imported images to create all scenes and objects. Upon entering the museum, there are three areas, including a video tutorial area, an energy introduction area, and a gaming assessment area, all structured according to the scene diagram as shown in Figure 1.

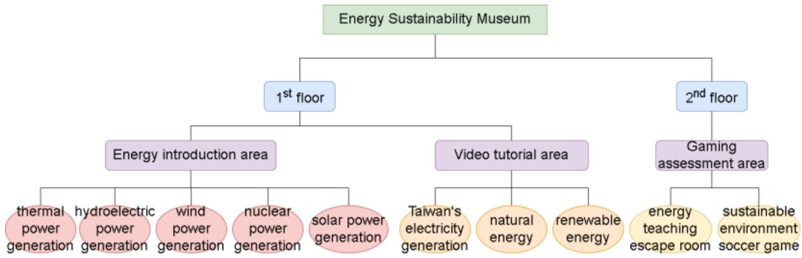

Figure 1: Scene framework diagram

On the first floor of the museum, there are two areas for students to explore. The first is the video tutorial area, which features three videos: Taiwan's electricity generation methods, natural energy, and renewable energy. These videos offer a quick introduction to the topic of energy and sustainability. The second is the energy introduction area, which includes five different types of power plants: thermal, hydro, wind, nuclear, and solar. Through these exhibits, students can interact with and operate simulations of various types of power plants.

On the second floor, students can learn about energy and sustainable environment-related knowledge and then test their knowledge through the gaming assessment area. The first section is called Energy Teaching Escape Room, which features power generation introduction and test comprised of true/false questions. Students must click on the door to answer the questions to escape the room, and if they answer correctly, the door will open. If students answer incorrectly, a butterfly beside the door will provide hints to help them progress. The second section is the Sustainable Environment Soccer Game, which features a sustainable environment test composed of four multiple-choice questions. Students have to kick a soccer ball to knock down a column with the correct answer, while an attendant explains the answer. Once all questions are answered correctly, students can click on a door to exit.

3 The Energy Sustainability Museum

3.1 Museum Hall and Video Tutorial Area

The Energy Sustainability Museum can be reached via https://edu.cospaces.io/LVG-DEG. Entering the museum hall, the walls of the lobby are adorned with posters of the 17 SDGs of the United Nations, with a special emphasis on Goal 7: Affordable and Clean Energy—ensuring that everyone has access to affordable, reliable, sustainable, and modern energy. This serves to provide visitors (i.e., students) with a quick understanding of the purpose of the venue, while also acquainting them with the SDG goal patterns (as shown in Figure 2). In the video tutorial area, there are three educational videos which cover Taiwan's electricity generation, natural energy, and renewable energy. By watching these videos, visitors can gain a quick understanding of the energy sources currently available in Taiwan, as well as the related knowledge of sustainable energy. This provides visitors with a fundamental comprehension of energy sustainability.

Figure 2: Museum hall and the first floor scene

3.2 Energy Introduction Area

In the energy introduction area, there are five power generation scenes, including (1) thermal power generation, (2) hydroelectric power generation, (3) wind power generation, (4) nuclear power generation, and (5) solar power generation. Clicking on each power plant will take the visitor to the corresponding scene, where they can first view the surrounding construction and then proceed with interactive guidance and explanation.

Upon entering the thermal power plant, visitors are welcomed by a guide. As they proceed further, they can view pictures and diagrams explaining the operation and power generation principles of thermal power (as shown in Figure 3). To facilitate a panoramic view of the thermal power plant, a flight mode has been specially designed for visitors to fly to the sky via the adjacent passage. After that, visitors can return to the venue and use the portal to move on to the next scene, hydroelectric power generation.

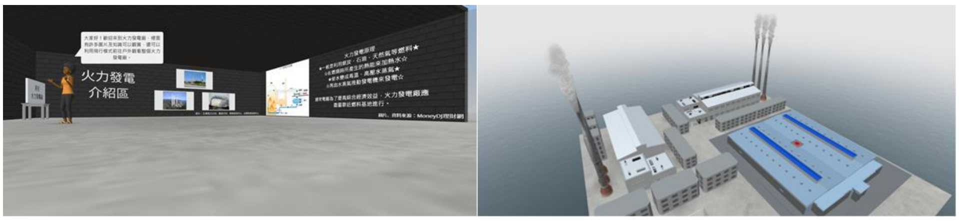

Figure 3: Thermal power generation scenes

Entering the scene of hydroelectric power generation, the guide introduces the layout of the venue. Then, following the instructions, visitors board a boat and can enjoy the scenery of the entire reservoir during the ride. Reaching the shore, visitors can see pictures, diagrams, and explanations of the hydropower generation process (as shown in Figure 4). After viewing, visitors can cross a small bridge and use the portal to proceed to the next scene, the wind power generation.

Figure 4: Hydroelectric power generation scene

Entering the scene of wind power generation, visitors will be greeted by an attendant who will explain the facility layout. In the background, there are pictures, exploded views, and the principles of wind power for electricity generation (see Figure 5). We also added a video to provide visitors with a more in-depth understanding. Once the tour is completed, visitors can move on to the next scene, nuclear power generation, through the portal.

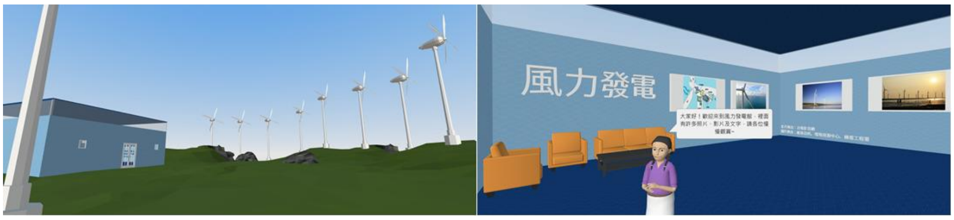

Figure 5: Wind power generation scenes

After entering the nuclear power plant scene, visitors will be guided by the plant's staff who will provide an explanation (see Figure 6). Inside the facility scene, there are pictures and diagrams explaining the power generation principles, which can be viewed by clicking on bulletin boards. Once the tour is completed, visitors can use the portal to move to solar power generation.

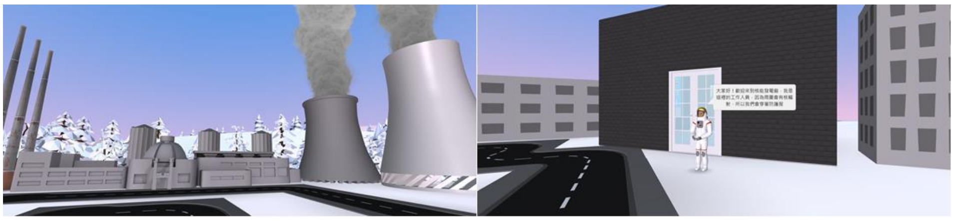

Figure 6: Nuclear power generation scenes

Upon entering the scene of solar power generation, a flying mode is provided to allow visitors to view the entire solar power scene. After viewing the scene, visitors enter the museum where the guide will introduce the exhibits (as shown in Figure 7). There are also videos and pictures behind the exhibits explaining the principles of solar power generation. After the visit, visitors can return to the museum through the portal and participate in game quizzes.

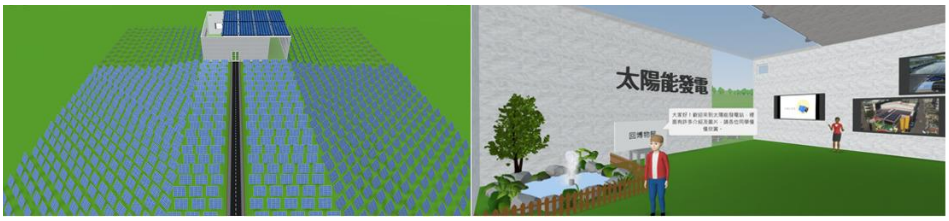

Figure 7: Solar power generation scenes

3.3 Gaming Assessment Area

On the second floor, visitors will see two sections of the gaming assessment area. The first assessment area is the Energy Teaching Escape Room. It consists of ten levels, each with different animals and corresponding habitats. Knowledge boards are placed on the animals to allow students to understand relevant information before answering true or false questions. By clicking on the door to answer, when answered incorrectly, a small butterfly next to the door will provide an explanation for the student to pass the level (see Figure 8).

Figure 8: Door opens when answer is correct

The second assessment area is Sustainable Environment Soccer Game. It consists of four levels with multiple-answer questions. When answered incorrectly, the pillar in front will not fall, and an explanation will be provided by the announcer on the side. Supplementary explanations will be given upon answering correctly and knocking down the pillar. Once all the questions are answered correctly and the pillars have fallen, the door will open, allowing you to move on to the next level (as shown in Figure 9).

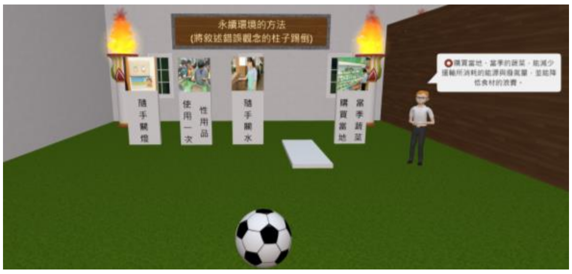

Figure 9: The correct answer and a supplementary explanation given after the pillar has fallen

4 Concluding Remarks

The present study developed a vivid VR learning environment called Energy Sustainability Museum, which was designed and developed around the thematic concepts of energy and sustainability. In Taiwan, the content related to energy sustainability in the Science and Technology curriculum for elementary schools is relatively limited, with few supplementary learning resources available. Thus, this study aimed to integrate situated learning and operational learning into a VR learning environment, through interactive and hands-on operations, to enhance students' knowledge and understanding of relevant concepts. By utilizing VR technology, this study hopes to increase interactivity of the learning experience, helping students to comprehend the importance of sustainability and providing teachers with a novel teaching and learning method.

The Energy Sustainability Museum can serve as a supplementary learning resource on the topics such as resource development, natural resources, and sustainable management in the fields of science and technology for young students interested in these issues. Future research should investigate the effectiveness of introducing this VR learning environment to school classrooms using VR technology such as head-mounted displays or mobile VR. It is hoped that this VR learning environment can better engage students and improve their understanding of energy and sustainability, and allow the related SDGs to take root in elementary school curriculums.

Acknowledgement

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