Applying Virtual Reality to Teaching the Law of Conservation of Energy in Physics

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Abstract.
This paper explores the use of virtual reality in developing educational materials for the conservation of energy law in the field of natural sciences, specifically focusing on gravitational potential energy and elastic potential energy. Through immersive experiences in virtual reality, students are provided with an enjoyable learning opportunity. The visual experience in virtual reality is designed to simulate scenarios involving three different gravitational fields of planets, allowing learners to break free from the constraints of reality and experience the conversion between potential energy and kinetic energy within the context of energy conservation. Students are immersed in an engaging learning environment, where they can truly grasp the essence of Newtonian mechanics.

Keywords: Virtual Reality, The Law of Conservation of Energy, K12 Education.

1 Literature discussion

For the teaching physics in the natural field of primary and secondary schools, gamification teaching can provide students with experience in learning the basics of science. Even Jean Piaget, the founder of cognitive psychology, discussed the effectiveness and importance of learning through games [1]. With the gamification of educational methods, teachers should use their imagination and create solutions across disciplines. Intensify knowledge learning by developing cognitive processes (perception, attention, memory, thinking skills). [2] Virtual reality technology has been proven in K12 science classrooms to enhance the learning experience, thereby increasing achievement and motivation. This is the teaching method of Inquiry-Based Learning (IBL). [3]

In this paper, virtual reality technology is applied to the teaching of the law of energy conservation in physics, and game-based interactive content is designed to achieve innovative basic education content in physics and astronomy.

2 Methods and steps

In the field of science and technology education, Burke (2014) revised the 5E teaching circle and proposed the 6E teaching mode, which is student-centered, and aims to strengthen the design and inquiry ability in STEM education. [4] The six processes include: 1. Engage2. Explore 3. Explain 4. Extend/Elaborate 5. Enrich 6. Evaluate. Each cycle of the 6E teaching mode is a process that represents a complete unit. Because students need to keep thinking during the process, it will be a teaching process that is quite suitable for STEM teaching. The project is designed with the teaching steps of 6E, as follows:

1. Engage

Based on the physical mechanism of the roller coaster and bungee jumping, the design students use the first-person viewpoint inducing think about physical phenomena in the immersive experience.

2. Explore

The content design students have interactive experiences in three different gravitational fields of the earth, the moon and Mars, and guide them to explore and compare the differences.

3. Explain

In VR content, the left-hand controller is designed as a tablet to assist students who need to understand the principles in depth. While playing, they can turn on the tablet at any time to read more detailed explanation and theories on learning.

4. Elaborate

During the VR playing, the user interface displays the current altitude, speed, kinetic energy and potential energy values. Learners can compare differences and deepen their experience with physics formulas.

5. Enrich

The content design can adjust the height of roller coaster or displacement of the bungee jumping spring for interaction, that students can deepen their understanding of exploring the principles of physical mechanics and guide they are interested in natural science.

6. Evaluate

Compare pre- and post-teaching examination to check whether students have achieved the learning goals.

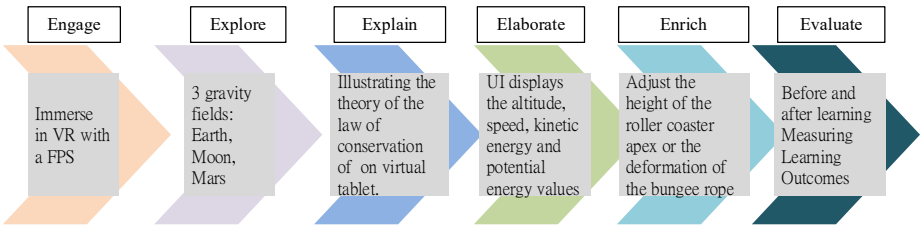

Fig. 1. 6E Design flow chart

2.1 Energy Conservation Law—Gravitational Potential Energy

The content is designed for K6 to K9 students. The objective is teaching as energy conversion between gravitational potential energy and kinetic energy. The gravitational potential energy is proportional to the gravitational field and height. The course design takes the roller coaster as an example and uses virtual reality to design three different gravitational fields with the earth's gravitational acceleration of 9.81 m/s^2, the moon's gravitational acceleration of about 1.625 m/s^2, and Mars' gravitational acceleration of about 3.724 m/s^2.

The roller coaster is gradually pulled to a certain height and rising potential energy at this time. When the car slides down the slope, the height gradually decreases, and the speed gradually increases. The value of energy conversion can be clearly expressed through virtual reality simulation, which is helpful for students to observe and explore. Under the same height and roller coaster track conditions, student can intuitively compare the difference in the change of the gravity field and improve there's understanding of this phenomenon.

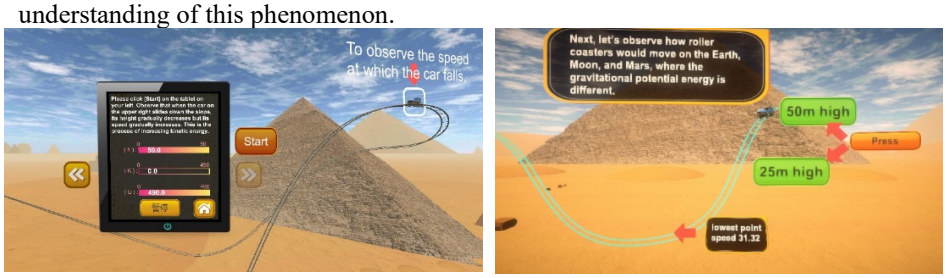

Fig. 2. The roller coaster rail track.

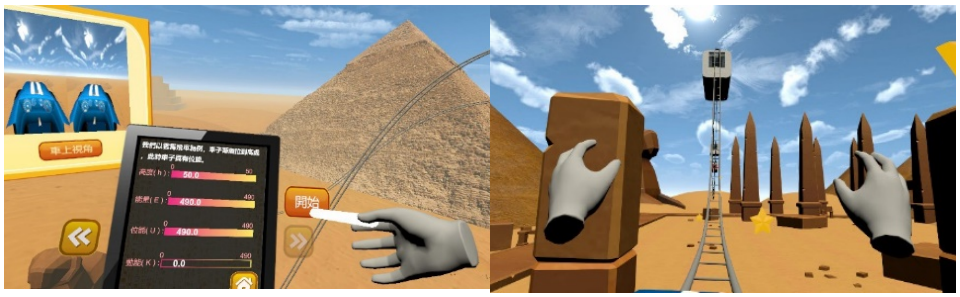

Fig. 3. The UI and Interaction of roller coaster.

The content is designed to interact with grabbing props, coins or bombs. The speed of grabbing objects corresponds to the speed of the car, to deepen the feeling of the speed of the car.

2.2 Energy Conservation Law—Elastic Potential Energy

The objective is teaching as elastic potential energy and kinetic energy conversion. The elastic potential energy is the potential to the elastic body due to deformation, which is proportional to the square of the spring coefficient k and the deformation.

Elastic potential energy is

$$\frac{k\Delta^2}{2} \tag{1}$$

Kinetic energy is

$$\frac{mv^2}{2} \tag{2}$$

Those two-energy store in different ways. In virtual reality simulates the first-person point of view to feel the change of speed in the jumping cockpit, and the UI is designed to display the values of elastic potential energy and dynamic potential energy in real time, convenient for students to observe.

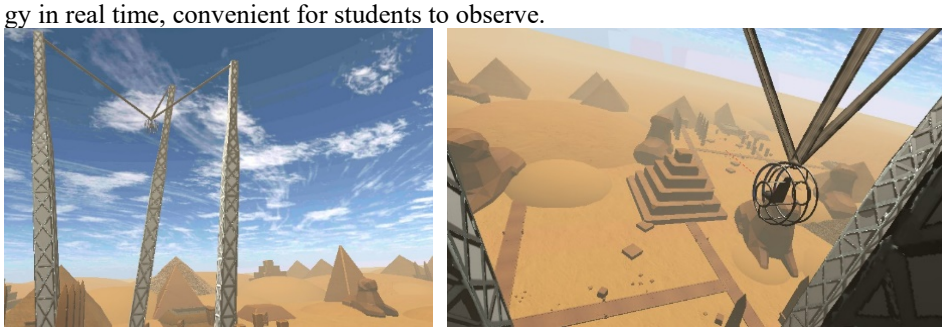

Fig. 4. A figure of bungee jumping car in VR.

3 Research results

This VR content tested in Chong-Lin Junior High School in New Taipei City on December 30, 2011. Total of 24 students completed the course study. The results of the pre- and post-learning tests are shown in the table below.

Table 1. Comparison table of test questions and learning outcomes.

No	Question	pre-test correct rate	post-test correct rate
1	Under the same condition of shape and height of the orbits are, if you take a roller coaster on the earth, the moon, and Mars, which planet will you go down the fastest?	65%	100%
2	Comparing the roller coaster moving to a height of 50 meters on the earth, the moon, and Mars, which planet has the greatest gravitational potential energy?	58%	92%
3	Raise a 5 kg object by 2 meters from the ground, if the gravitational acceleration is 9.8 m/s2, how many joules is the potential energy of the object?	58%	81%

4 Conclusion

Comparing the test results before and after learning, the immersive of virtual reality is used to explain the physical phenomena of the law of energy conservation, which can promote students' understanding of abstract formulas.

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