Exploring Input Devices for Supporting Virtual Magnet Experiments for Third Grade Students

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Abstract

COVID-19 pandemic has inhibited many students from receiving proper education. Especially, classes such as science courses had the biggest impact due to not being able to learn through conducting experiments. To resolve this problem, we present a virtual reality-based system, where we reproduced a science lab for students to conduct magnet experiments without needing real-life equipment. We focused on the third grade elementary school magnetism related science experiments, since this is the first content that requires lab experiments in a child's science curriculum in South Korea. The system supports three different input devices (a keyboard, a hand-held controller, and a sensor for bare hand gestures), known to vary in terms of the level of immersion and usability, which can affect one's learning performance. We conducted a user study to evaluate the system's usefulness in learning the basic magnetism properties and identify which input device is the most compatible in using the system. The results revealed that the keyboard has the best usability, while the sensor for bare hand gestures is the most realistic and provides the best immersion.

Keyword

Elementary physics experiment, virtual laboratory, magnetism, input device

1. Introduction

Recently, COVID-19 pandemic made a significant impact in the field of education. Multiple countries had to be quarantined for a long period due to pandemic, and students were not able to attend schools and receive proper education. This decreased the amount of time for students to be educated and study at schools, which disrupted their academic performance [1]. This is especially a significant issue with science classes, since learning through conducting experiments is proven to be an effective way of learning [2]. Unfortunately, regular e-learning courses are incapable of providing the proper skills and knowledge regarding laboratory experiments [3]. On the other hand, virtual labs effectively reproduce the advantages of real-life laboratories of providing the appropriate skills for science learners, while being more accessible [4].

We present a system based on a virtual environment, where students can remotely conduct science experiments without requiring real-life laboratory equipment. Our virtual science lab mainly focuses on third grade students' magnet related experiments, as this is when students first start learning science through conducting experiments and learning about magnetism is the first lab-based curriculum. Based on the prior research claiming that selecting a proper input device is important since its influence in the users' experiences and immersion may differ [5], we implemented the system to support three input devices (1) a typical QWERTY keyboard (2) a handheld controller (i.e., Vive Pro Eye controller) (3) a sensor for detecting bare hand midair gestures (i.e., Leap Motion). We designed three experiment scenarios to demonstrate the usefulness and suitability of the input devices. To evaluate these criteria, we conducted a user study with 6 participants where they were presented to the three input devices in a random order. After using each device to finish all three scenarios, there was a short interview. After completing the three scenarios with all three devices, we conducted an additional interview regarding the overall usability system and the evaluation of the input devices. Through the study, we demonstrate the potential of the virtual science lab system and which input device has the best compatibility with the system.

2. Related Work

2.1 Science education platform using VR/AR

Multiple research has been conducted focusing on the use of virtual reality in reproducing a science lab where students can perform experiments. As an example, Aoki et al. [6] acknowledged that it has become important to utilize virtual reality (VR) and augmented reality (AR) for educational purposes, they designed VR and AR teaching aids appropriate for middle school science education. Moreover, Yair et al. [7] presented a virtual environment-based dynamic 3D model of a solar system targeting primary and secondary school level students, which will be used as an effective aid for teaching astronomy due to its powerful scientific visualization techniques. For biology education, Weng et al. [8] developed an augmented technology system which presented the process of meiosis and cell respiration.

Several research studied the effect of using VR for educational purposes, such as whether it can enhance students' understanding and increase their academic performances. For example, Park et al. [9] presented an application of visualizing 3D magnetic fields for elementary school virtual science experiments and revealed that such a method significantly improves the students' capabilities of presenting the magnetic field. Also, Pyatt et al. [10] compared the students' attitudes between physical and virtual science labs and concluded that while students showed a positive attitude for both types of labs, they found virtual lab experiments to have a better equipment usability as well as a higher degree of open-endedness.

Moreover, some research focused on using VR and AR to enhance the visualization effects, which make students understand clearly. As an example, Mannuβ et al. [11] presented an AR-based learning aid system that depicts the magnetic lines visibly, which tracks the real-life magnet and calculates its magnetic field in real time, to help students in understanding the concept of magnetic field. Also, Matsutomo et al. [12] introduced a real time visualization system which visualizes both the magnetic field of a single magnet and the magnetic field generated by the line currents.

2.2 Science classroom with applying VR/AR

A number of research investigated the effect of VR and AR systems when applied to the actual classroom. Aoki et al. [13] developed an AR magnet which can be used as an AR marker. They compared the test results between the traditional lab experiment and the AR-based lab experiment, and revealed that the AR-based experiment received a higher test result. Also, Fidan et al. [14] presented FenAR, an education application based on AR, and conducted a user study where two student groups were required to solve problem scenarios in a different environment. This revealed that the student group asked to solve the problems with FenAR showed better achievements than the group that did not. Cai et al. [15] developed the AR system with Kinect, which shows magnetic field line and conducted a user study applying this system to two student groups, where one used a real magnet bar and the other used the system to conduct an experiment. The test, which was taken after this experiment, revealed that the group that used the system showed a better achievement. Similarly, Liou et al. [16] developed a virtual classroom and compared two student groups' test scores of when learning through the virtual classroom and the traditional classroom, which showed that the student group that used the VR system achieved higher scores than the group that did not. Chernri et al. [17] introduced VR in a geoscience classroom and allowed students to easily comprehend geological features in 360 degree images.

3. Main Study

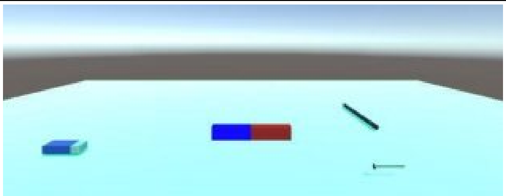
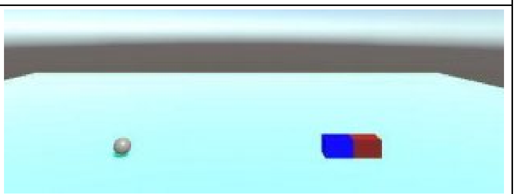
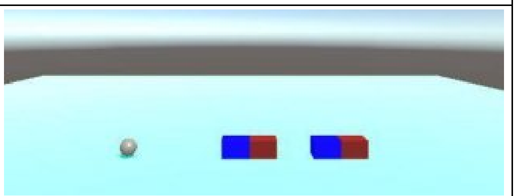
3.1 Participants

We recruited 6 participants (all female) to participate in the main study. The average age was 23.67 (SD = 1.24). To identify whether the system has the potential in enhancing the learning effectiveness in science education, we conducted the main study only with adults.

3.2 Apparatus

The virtual science lab system was implemented using Unity 2020.3.7f1 with a computer that has an Intel Xeon Bronze 3106 CPU with 64.0GB and NVIDIA Quadro P40000 graphics card. For the three input devices, a keyboard, a right-hand side controller of Vive Pro Eye, and Leap Motion were used and a computer monitor was used as the output device. The magnet related assets were downloaded from the Unity Assets Store. The participants were given three magnet related experiment scenarios to perform with all three input devices. The virtual magnet bar possessed the same properties as a real-life magnet bar, such as having the ability to attract magnetic objects. We limited the magnet's movement to only move among the surface of the two-dimension plane. The details about the three experiment scenarios can be found in Table 1.

Table 1. Scenario overview

	Overview
Scenario1	
Scenario 2	
Scenario 3	

- 3.2.1 Scenario 1

The participants were required to move the magnet that is placed between the objects and identify which object is magnetic. The presented objects differed between the devices.

- 3.2.2 Scenario 2

The purpose of this scenario is to understand the relationship between an object's mass and the magnetic force. A ball and the magnet were placed at the left and the right side of the screen, and the participants were required to move the magnet slowly to the left. This scenario was repeated twice with a ball each, which differed in its mass. Participants were asked to identify a ball that has a larger mass.

- 3.2.3 Scenario 3

The goal of this scenario is to understand the relationship between the number of magnets and the total magnetic force. A ball and two magnets that are aligned horizontally were placed at the left and the right side of the screen respectively. The participants were asked to initially wait for 5 seconds then connect both magnets and observe the ball's movement to identify which case has the higher magnetic force.

3.3 Conditions

The main purpose of this study is to identify the potential of the virtual science lab system in teaching students the concepts related to magnetism and conducting science experiments. Moreover, we aim to investigate the most suitable type of input device for conducting virtual science experiments among the three input devices, a keyboard, a controller of Vive Pro Eye, and Leap Motion. The input devices were given to the participants in a random order.

- 3.3.1 Computer Keyboard

A computer keyboard was connected to the computer, where its monitor was used as the output device. The participants used the arrow keyboards to move the magnet.

- 3.3.2 Vive Pro Eye controller

A controller of Vive Pro Eye is a virtual reality device. We limited the participants to only use the right-hand side controller. The participants moved the controller without pushing any buttons to move the magnet.

- 3.3.3 Leap Motion

This is a hardware device designed by Ultraleap, which tracks bare hands and captures its movements or gestures. The participants grabbed the magnet with their right hand and moved their hand while holding the magnet to move it.

3.4 Procedure

After having the participants sign the consent form, we first briefly explained the overall process of the study and what types of devices will be used. Then we introduced the first type of device they will be using and gave them time to familiarize with the device by showing a short tutorial and letting them practice. Then, we had the participants perform all three scenarios with an explanation of how to perform the scenario before starting each scenario. After finishing the scenarios with the first device, we conducted a short interview. The second and the third device went through the same process. After the participants finished performing all three scenarios with the three input devices, we asked them which device they preferred the most for all scenarios, which device they perceived to be the most suitable in conducting virtual science experiments.

4. Findings

4.1 Keyboard is the most usable input device.

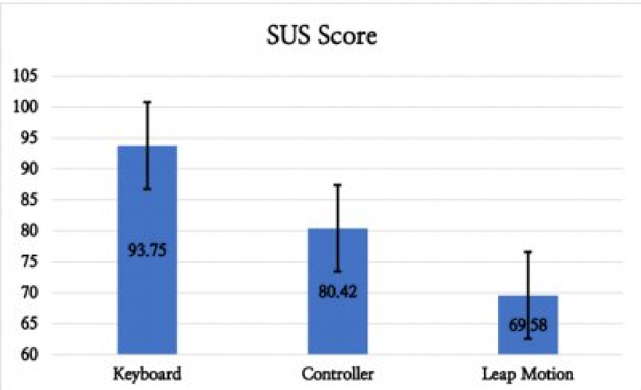


Figure 1 SUS Score of each device

To evaluate the usability of each input device, we asked the participants about the overall usability of the system of each input device based on the System Usability Scale (SUS). As a result, each input device, keyboard, Vive Pro Eye controller, and Leap Motion received a score of 93.75, 80.42, 69.58, respectively. To be specific, in terms of difficulties in learning, keyboard, controller and Leap Motion received a score of 1.08, 2.33, 1.83, respectively. Several participants (P1, 3, 4) mentioned that the keyboard is the most preferred device due to its familiarity and ease of use. On the other hand, the controller was chosen to be the least preferred device because participants had to move the controller much more than they expected, which caused fatigue.

4.2 Leap Motion provided the most realistic and immersive sense

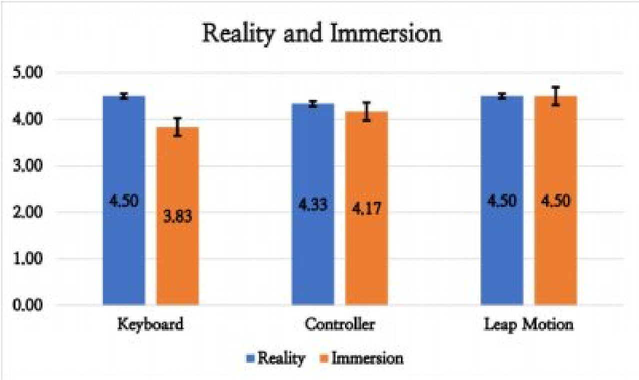


Figure 2 Reality and Immersion score of each device

To identify if the most usable input device differs from the input device that provides the most realistic sense, we asked the participants to give a score in a 5-point Likert scale regarding how realistic each input device is. As shown in Figure 2, the Vive Pro Eye controller received the lowest score of 4.33, while the keyboard and Leap Motion received the same score of 4.50. P5 commented, “With Leap Motion, I can hold and grab the magnet as if it is real.”

Moreover, as revealed in Figure 2, for the case of immersion, the participants perceived Leap Motion to provide the highest immersion and gave the score of 4.50. On the other hand, the keyboard provided the least immersion with a score of 3.83.

4.3 Leap Motion is the most suitable device to use with virtual science lab

Table 2 The number choosing suitability of each device

Suitability	Keyboard	Controller	Leap Motion
Most	1	0	5
Least	2	3	1

To understand which device is the most suitable for students to effectively learn and conduct science experiments with the system, we asked the participants regarding this issue. As a result, the most suitable device was Leap Motion and the least suitable device was the controller. All the participants except P4 chose Leap Motion as the most appropriate input device due to its ability to provide the best realistic and immersive sense. On the other hand, half of the participants answered that the Vive Pro Eye controller was the least suitable device because it was relatively harder to control than keyboard and was less realistic than other two devices. Further results can be found in Table 2.

5. Discussion

The findings of our study reveals that while the keyboard is the most usable input device when conducting science experiments in a virtual environment, Leap Motion is the most realistic and provides the best immersion. Keyboard has already been familiarized through long term practice but because the participants have to move the magnets in a less intuitive way, such as pushing the buttons on the keyboard to move the magnet, it was much less realistic than Leap Motion. The same reason can be applied to the Vive Pro Eye controller regarding the lack of realistic sense. On the other hand, even though the participants were unfamiliar with the Leap Motion device, they perceived it to be the most realistic and immersive because of grabbing and moving the magnet in an intuitive way. Overall, the participants perceived the devices that require actions that are the most similar to the real world as the most suitable device for the virtual reality-based system.

6. Conclusion

We presented a virtual reality-based magnet laboratory system for third grade students and identified that the system has the potential to be an effective learning aid for children in learning science. Also, among the three input devices, even though the keyboard seemed to be the most usable device, Leap Motion was the most suitable for the system.

We plan on revising several parts of the system in the future. First, because this system is to be used on elementary level students, it would be better to have fun factors that can appeal to students' interests, such as allowing them to explore with magnets and conduct their own science experiments. Moreover, in the current phase, we used the computer monitor as the single output device while having multiple types of input devices because the Head Mounted Display (HMD) of Vive Pro Eye can be very heavy for young children. However, if the HMD becomes lighter and easy to use in the future, it would allow students to experience a more immersive virtual science lab. We also acknowledge that there might be some recognition problems regarding Leap Motion, since the device is not designed for small hands.

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