International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Application Development for Education on Scientific Experiments in Virtual Reality

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Abstract*: Since the late 1980s, we have begun to hear the word "disinterest in science". On the other hand, recently, virtual reality (VR) technology that creates artificial environment by computer has been considerably developed. The VR is currently being utilized in various fields such as scientific visualization, medical care, education, training, tourism, and entertainment. Further it is possible to obtain an ideal environment that is difficult to realize in real space, and it is easy to change natural constants. Accordingly, we developed a prototype VR system that anyone can easily perform scientific experiments such as physics and chemistry with simple operation. In this way, this system makes it possible to perform free simulations by setting the ideal environment without the need for preparation and tidying up. Further, considering the cost burden of the user, we suggested a new system on a platform which can be easily prepared by using a smartphone. Furthermore, in this paper, we conducted a questionnaire survey to confirm the effectiveness of this system.

Keywords : Virtual Reality (VR), Education, Physics experiment, Chemical experiment, Smartphone.

I. INTRODUCTION

Since the late 1980's, the word "disinterest in science" has been reported in newspapers and magazines. In the White Book on science and technology published in 1993 [1] said that it is acknowledged as a fact that "young people are not interested in science" is progressing.

However, in question that "Do you like observations and experiments in science?", they answered "agree" or "agree a little". And it accounts for a large proportion, 80.2% [2]. However, the opportunity of experiments and observations is almost lacking at schools. Moreover, according to a survey on science education in junior high school, the percentage of science teachers who answered "time for preparation and tidying up is not sufficient" during experiments and observations was 66%. Also, 54% was "lack of equipment" and 34% was "lack of laboratory", and these showed to be a hindrance to opportunities for school experiments and observations [3].

On the other hand, computer simulation is very important in physics, and it is widely used in science.

In the field of physics education as well, its effectiveness has attracted attention for a long time, and various techniques have been developed and used independently.

It is possible to obtain an ideal environment that is difficult to realize in real space, and it is easy to change natural constants.

In addition, it is also possible to visualize things that cannot be seen visually or measured by machines, and it is also possible to repeat simple tasks.

Therefore, it has been used for a wide range of educational purposes to confirm the physical phenomenon when the experiments are difficult to realize [4].

Many platforms were developed for VR in 2016, and it became possible to easily access VR technology if you possess a smartphone or tablet terminal.

At present, VR is attracting attention as a technology that can easily experience what is difficult to do in reality.

According to MMD Research Institute and Intel Security survey of smartphone ownership for high school students and junior high school students in 2016 [5], 93% of high school students and 40.9% of junior high school students possess smart phone in Japan.

In addition, L. Sheehy [6] says that it is easier to maintain the motivation if it is possible to repeat the training in the game sense, and it is easy to get good results.

In this study, anyone can easily conduct scientific experiments with simple operations, create a scientific experiment application with VR with immersive, and aim to help improve "disinterest in science". Furthermore, in consideration of the burden on users, we develop a scientific experiments application with VR for smartphone so that users can interact easily with the experiment.

In related study [7], when it comes to the user to put the liquid into the container, spill the liquid from the container, and scoop the liquid, the action on the liquid is expressed with a higher sense of reality such as waves, vortices of the liquid surface, and color changes.

Manuscript published on November 30, 2019.
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This makes it possible for users to virtually experience the chemical reaction between the liquids performed in science experiments. However, it requires a specific device for high expressiveness and realism, and it is not possible to experiment in the virtual world easily. Thus, in this study, we solve this problem by using a smartphone that anyone can easily handle as a platform.

II. RELATED WORK

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III. METHODS

In this study, we develop educational applications for chemical and physics experiments.

In development, we use Unity that can handle multiple platforms, add physics operations to objects, edit in real time while playing, also use Blender with functions such as modeling, rendering, and animation creation.

We use Google Cardboard as shown in Figure 1 in VR simulation.
If the user tilts the headset horizontally or vertically, it will be reflected in the virtual world.

By looking at the object, the point becomes a circle, and can select by pressing the button of Cardboard (see Figure 4). The VR chemical experiment simulation is shown in Figure 3 to Figure 6 and the physics experiment simulation is shown in Figure 4 to Figure 10.

Fig. 2.Google Cardboad with Android smartphone.

IV. CHEMICAL EXPERIMENT

For chemical experiment in this study, we develop it focusing on the theme of "Separation of metal ions". Separation of metal ions is suitable for education in the VR because it is easy to remember about the color procedure that occurs when reacting with each solution, and it tends to remain in the impression. However, it is also the reason for choosing few opportunities to see actual reactions. It is also a subject to be presented as an exam question, and was also adopted at Miyazaki University in the past. An example is shown in Figure 2.

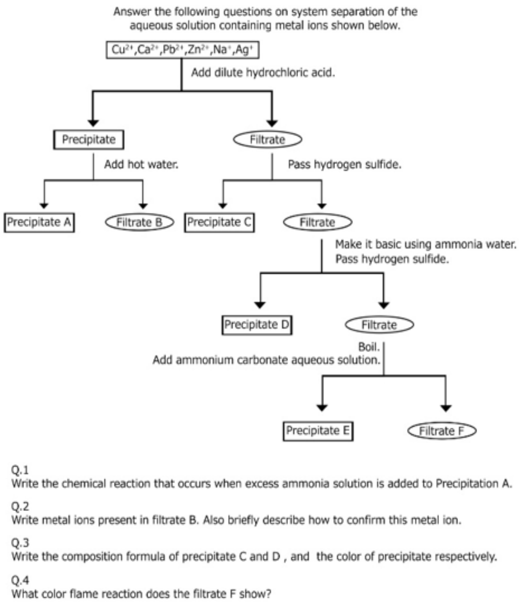

Fig. 3.Exam question.

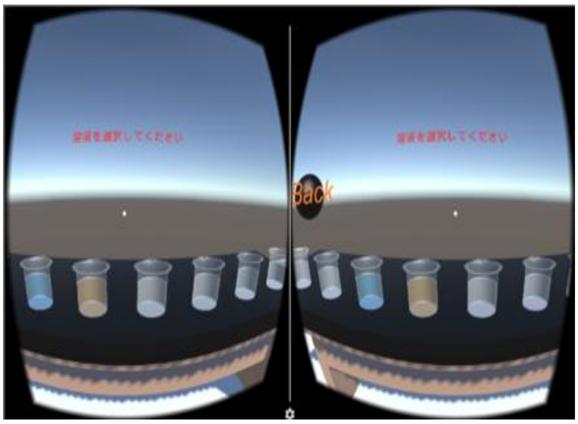

Fig. 4.Start in chemical experiment.

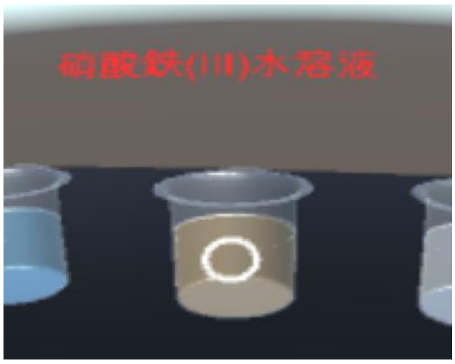

Fig. 5.Select.

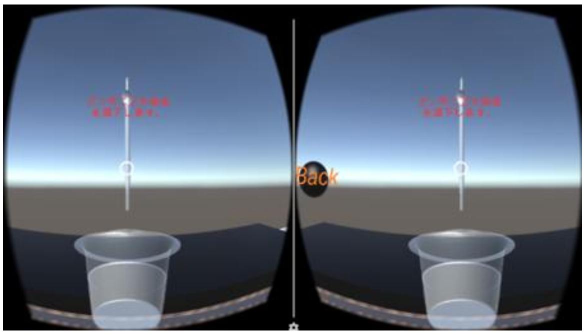

Fig. 6.Dripping.

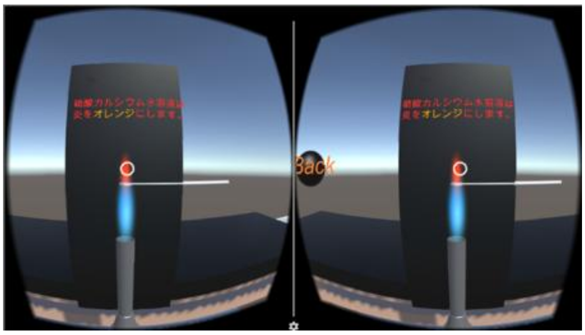

Fig. 7.Flame reaction.

V. PHYSICS EXPERIMANT

For physics experiment in this study, we develop a physics simulation of “Pendulum motion” (see Figure 8), “Falling motion” (see Figure 9), “Projection motion (horizontal projection / free fall)” (see Figure 10).
The user can change these motions in “Select scene” (see Figure 7).

In “Pendulum motion”, we measure the weight by hanging a weight on the thread and changing the length and runout width of the thread.

In the “Falling motion”, the falling speed is controlled by rolling the ball while changing the angle of the slope, and observe how the velocity of the falling object changes in the process of falling. In “projection motion (horizontal projection / free fall)”, simultaneously project the sphere in both the vertical direction and the horizontal direction while changing the height and the initial velocity, and observe that both spheres simultaneously reach the ground.

These experiments required large experimental tools, and since it is sometimes difficult to obtain accurate numerical values, we considered that they are suitable for experiments performed in virtual environments.

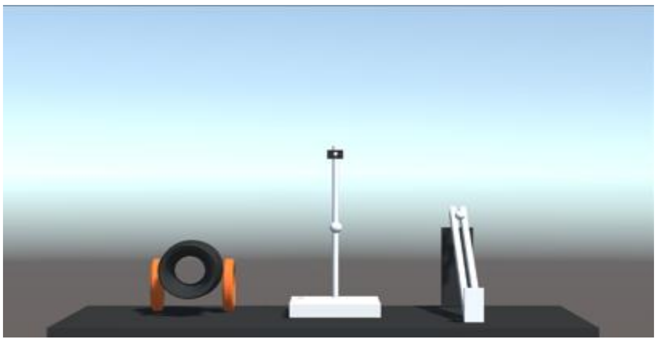

Fig. 8.Select scene.

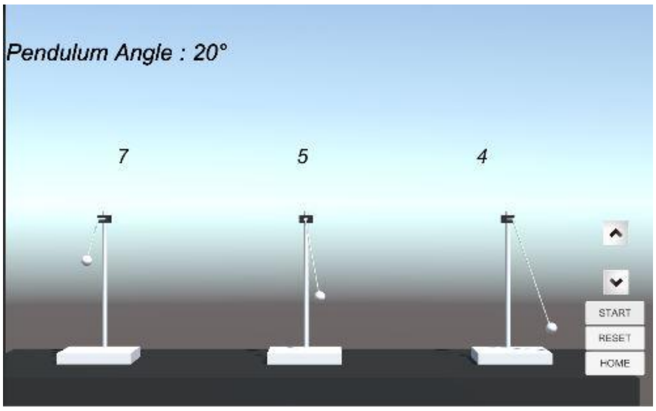

Fig. 9.Pendulum scene.

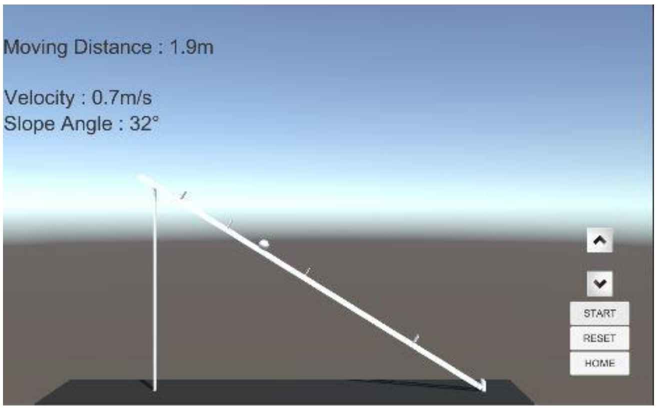

Fig. 10. Falling scene.

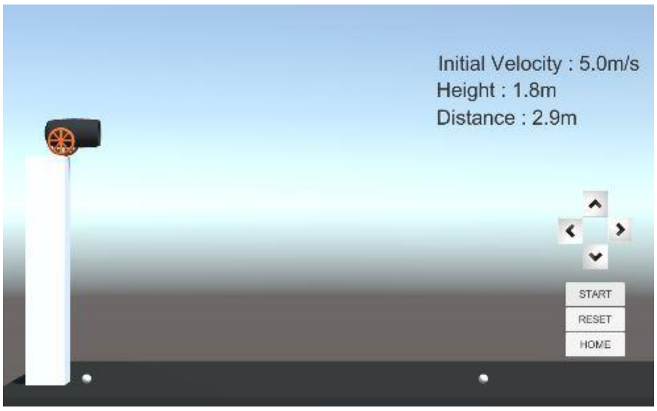

Fig. 11. Projection scene.

VI. EVALUATION EXPERIMENT

We conducted a questionnaire survey in order to confirm the usefulness of the developed application for chemistry and physics experiment.

A. The VR Chemical Experiment Simulation

We conducted a questionnaire survey for 12 students to evaluate.
In this experiment, we prepared the VR version to be performed on a smartphone and the normal version to operate on a PC, and have them operate them in order.

Also, in consideration of the possibility that the result such as immersive changes depending on the order of execution, we divided them into two groups.

Group 1 is the group that the group members operate VR version at first.

Group 2 is the group that the group members operate PC version at first.

Group 1 is given a 5-minute pre-test (see Figure 2) prior to conducting the experiment, and a 10-minute operation of the VR version.

After the operation, the subjects take a 5-minute post-test and operate the PC version for 10 minutes.

And, we have the subjects fill in the questionnaire survey at the end. Post-testing is done by randomly choosing from 5 questions that are different from pre-testing (all in the same form).

We also conducted the same experiment for Group2.

Questionnaire survey includes 5 ratings.

The best results is 5 point and worst results is 1 point for Item 1 to Item 6 questions. In addition, Item 7 to Item 8 are free descriptions.

The contents of the questionnaire survey are the following eight items.

1. Was the VR experiment fun?
2. Was the operation easy to understand?
3. Was the experiment result easy to understand?
4. Which of the VR and PC versions was immersive?
5. Would you like to do it if there are other experiments or subjects?
6. Which is better with PC version or smartphone version if you study repeatedly?
7. Were there any changes in your physics condition during or after the VR experiment?
8. Other.

B. Physics Experiment Simulation

We conducted a questionnaire survey for 5 students to evaluate the system's usefulness and usability. The contents of the questionnaire survey are the following four items.

1. Was it easy to operate?
2. Was the result of experiment easy to understand?
3. Was it easy to image physical phenomena?
4. Opinion and improvement point (free description).

Questionnaire survey includes 5 ratings.

The best result is 5 point and worst result is 1 point for Item 1 to Item 3 questions. Item 4 is freely described.

VII. RESULT AND DISCUSSION

A. About VR Chemical Experiment Simulation

We show the results of the questionnaire survey on Group 1 in Table-I and the results of the questionnaire survey on Group 2 in Table-II.

Both groups scored high on evaluation item 1.

Thus, it indicates that it leads to the motivation to learn repeatedly.

The results were also good for evaluation item 3.

We found that VR version is more immersive by the result of evaluation item 4.

The more immersive you are, the easier to remember as a memory based on the actual experience. Thus, it can be considered as an advantage to the VR version.

In the question of evaluation item 5, we found that user wants to try except for two people those who commonly answered in evaluation item 7 questions, "I feel sick, I feel nauseous".

In evaluation item 7, there were some opinions such as "I feel sick, I felt nauseous", and "I got tired eyes, and I had eyes hurt during the experiment" and those who answered it marked low points in evaluation item 6.

Table- I: Experiment results of VR chemical simulation in Group 1.

Item 1	*Item 2*	*Item 3*	*Item 4*	*Item 5*	*Item 6*
4.0/5	3.8/5	3.7/5	4.0/5	3.8/5	3.0/5

Table- II: Experiment results of VR chemical simulation in Group 2.

Item 1	*Item 2*	*Item 3*	*Item 4*	*Item 5*	*Item 6*
5.0/5	4.7/5	4.2/5	4.5/5	4.7/5	3.5/5

The results of pre-testing and post-testing of the experimenters in Group 1 are as shown in Table-III (max sore is 10).

In the post-test, the subjects raised 2 points than that of pre-test in average.

In evaluation item 8, there were opinions that "the letters are small" and "if you can lead the action, you can study crisply".

We show the results of the questionnaire survey by the average score in Group 1 and Group 2 of Table-III.

Looking at the average score of Group 1, it is lower than Group 2. The PC version only operates the mouse, but in the VR version the user has to move the head horizontally or vertically to make it more realistic.

Thus, we think that the reason getting such a result is that the operation is more difficult than the PC version.

Table- III: Experiment results of VR chemical simulation.

Pre-test	*Post-test*	*Group 1*	*Group 2*
1.8/10	3.8/10	3.7/5	4.4/5

B. About Physics Experiment Simulation

We show the average score of each evaluation item about the evaluation item 1 to evaluation item 3 in Table-IV.

In evaluation item 4, as good point, there were some opinions such as "the relationship between gravity acceleration and distance was easy to understand by sound" and "the trajectory of the sphere is easy to understand".

On the other hand, as improvement point, there were some opinions such as "I thought it would be easier to push the button a bit larger" and "I want a function like an oblique projection movement".

We got high evaluation in evaluation item 1 and evaluation item 2.

Thus, it turned out that this application is an application that anyone can use it easily.

However, in the evaluation item 3, although the average score itself was generally good, the evaluation was relatively lower than the above two evaluation items.

We think the reason is that it is difficult to image physical phenomena specifically on a small screen such as a smartphone.

Unity is characterized by being compatible with multiple platforms.

Thus, we think that we will be able to experience physical phenomena more realistically by making use of the advantages.

International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

In evaluation item 4, there were a lot of opinions about the expansion of the function. In particular, with regard to the projection movement, there was an opinion that it was better to be able to simulate oblique projection. Thus, this will be a future issue.

Table- IV: Experiment results of physics simulation.

Item 1	*Item 2*	*Item 3*
4.8/5	4.8/5	4.2/5

VIII. CONCLUSION

Recently, "disinterest in science" of young people has become a social issue.

On the other hand, VR technology has been considerably developed, and in the scene of learning, we know that the effect is enhanced by using VR and suitable for learning.

In order to solve this issue, we developed an application as prototype using VR technology for making it possible for school students to learn chemistry and physics easily.

We found that comparison between applications with VR and applications without VR shows that VR increases the value of experimental applications by our evaluation.

This study provides a solid foundation to improve the issue of "disinterest in science".

We will make it a realistic system by improving the issues mentioned in the discussion and further improving the contents of the experiment.

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Makoto Sakamoto received the Ph.D. degree in computer science and systems engineering from Yamaguchi University in 1999. He is presently an associate professor in the Faculty of Engineering, University of Miyazaki. His first interests lay in hydrodynamics and time series analysis, especially the directional wave spectrum. He is a theoretical computer scientist, and 2. his current main research interests are automata theory, languages and computation. He is also interested in digital geometry, digital image processing, computer vision, computer graphics, virtual reality, augmented reality, entertainment computing, complex systems and so forth. He has published many research papers in that area. His articles have appeared in journals such as Information Sciences, Pattern Recognition and Artificial Intelligence, WSEAS, AROB, ICAROB, SJI,IEEE and IEICE (Japan), and proceedings of conferences such as Parallel Image Processing and Analysis, SCI, WSEAS, AROB and ICAROB.

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Masamichi Hori profile which contains their education details, their publications, research work, membership, achievements, with photo that will be maximum 200-400 words.

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