LABBUDDY: A GAME-BASED INTERACTIVE AND IMMERSIVE EDUCATIONAL PLATFORM FOR PHYSICS LAB LEARNING USING ARTIFICIAL INTELLIGENCE AND 3D GAME ENGINE

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ABSTRACT

The concepts of physics play an important role in many fields of people's lives, and physics learning is abstract, challenging, and sometimes intimidating [1]. However, how to motivate students to learn physics in a fun way becomes a question. This paper develops a gamic, interactive, educational application to allow students to learn abstract physics in an illustrative way. We have implemented a visual physics lab by using a 3D game engine supporting the immersive environment of visualization and providing a playful learning tool for physics experiments at the same time [2].

KEYWORDS

Physics, Virtualization, Artificial Intelligence, 3D Game Engine.

1. INTRODUCTION

The learning of physics has become a mandatory class in education, and the experiments and labs are the most helpful tools to understand the concepts of physics. In most cases, students can only do experiments within the school labs; however, this limits them from re-do the experiments outside of the school, which results in students not fully interacting with the learning concepts, and it may cause students to have a lack of understanding and memorization. Learning the knowledge of physics only takes half part of the procedure, the other half is the operating step where students combine experiments in order to find out the relationship between physics functions and principles [3]. Therefore, the opportunity of doing experiments and labs in the learning of physics becomes an important issue that needs to be considered. For example, I had a deep impression about writing a report in my physics class. My group and I did an experiment during school time, but we were working on the lab report at home but we had a lack of memory on one of the experiment steps. We wanted to redo the lab but there is no place for us. I was really distressed at that time because the report was due on the same night. Therefore, I was thinking why couldn't we do it virtually? This idea guided me to do a lot of research and readings, and I finally decided to create a virtual physics lab that could benefit more students in learning physics.

David C. Wyld et al. (Eds): AI, AIMLNET, BIOS, BINLP, CSTY, MaVaS, SIGI - 2022
pp. 145-154, 2022. CS & IT - CSCP 2022 DOI: 10.5121/csit.2022.121814

There are many physics experiment simulators that have been published in public, which allow users to choose a specific lab or experiment. Users are free to put any values such as speed, gravity, direction, etc. However, these simulators are formed by a 2D platform where the users are only allowed to observe one side of the experiment [4]. Their implementations are limited in the experience of virtualization causing the users hard to see the changes on other sides during the experiment. In addition, the environment around the experiment is very shabby because the 2D platform method only provides a single background. A practical problem is that users are not able to immerse themselves in the experiment and it is hard to focus on details happening in the experiment.

Our goal is to create a virtual physics lab that allows users to choose any specific lab with appropriate inputs. However, our simulator is different compared to the others where the simulator is implemented as a 3D game engine instead of a 2D platform [5]. Within the virtual lab, users are free to walk around the lab, and there are different stations of labs placed in the lab room, and users can choose to play any of them. There are some good features of the virtual lab room. First, the experiment provides multi-angle observation that helps users to catch more details in the experiment. Second, the lab room is created as a virtual reality that makes an immersive feeling of doing the labs. Third, a short quiz will be generated to test the concepts of the experiment based on observation and operation. By doing this, it draws users' attention to recall the images of the experiment in order to have a deep understanding of the details. Therefore, we believe that our immersive educational platform of physics labs can effectively help users to get success in learning physics. In the early stages of the implementation, we have planned three different physics labs which are Magnetic Drop, Floating Egg, and Hot Water Pump.

Since the application is designed as a 3D platform, the virtual experience and virtualization of the labs are the most important keys of the application. We will create a checklist to test various features and functionalities of the virtual lab. The corresponding screenshots will be added along with the checklist in order to support the expected user experience. For example, the checklist will test the movements of the first-person perspective and make sure that the character can move freely within the virtual lab room. In addition, the experiment needs a different angle of observation in order to find out more details such as the lab of Magnetic Drop, which requires a top view to observe the moving speed of the object [6]. It is also necessary to include an observation angle testing in the checklist. We will carefully list all the testing areas in the checklist and test with a real machine demonstration to record how users could interact with our virtual 3D physic lab. In addition, the lab results will also be compared with the real experiments that will be finished in real life in order to evaluate the accuracy of the results. We will record the results of both happening in the application and the real life on the same table so that we can have a clear mind while comparing the results.

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Learning process of programming language and Unity

The first challenge was the learning process of programming language and Unity since the idea was to create a 3D virtual lab, Unity would be the first choice to accomplish it. However, this was the first time that I started to learn code, and I had no idea how I could implement code with Unity in order to reach my goal. I did a lot of research and watched different videos of Unity, then I decided to implement C# with Unity to do this project [7]. At the beginning of learning C#, it was a tough time since I was really new to the program, and the structure made me confused all the time. However, I was working hard and always researched when I had questions. I also set a schedule for each day in order to keep on track. The process turned out really well after I familiarized myself with C#, and I started to implement C# with Unity by doing a lot of exercises and testing.

2.2. Environment designing process for the virtual lab

The second challenge was the environment designing process for the virtual lab, and it took me a long time to figure out how to fit everything that I want in the virtual lab room. I first sketched a draft on paper and started to set up the environment on Unity by referring to the sketch; However, the Unity was not as easy as I had expected, the dimensions and scales were really hard to handle, and the things that were placed in the lab room looked messy. However, I took some extra time carefully calculating the dimensions and re-set the sizes of the objects. By doing this, it promised a learning environment in the virtual lab that provided immersive feelings for the users.

2.3. Converting the necessary physics functions into C#

The third challenge was converting the necessary physics functions into C# in order to keep the accuracy of the results showing in the virtual lab. The physics functions looked really easy to write by hand; however, it was hard for me to implement the functions in a programming language because some values need to be saved in different places. For example, the value x needed to be saved outside of the function, but the y value needed to be saved inside the function. I did deep research by watching different tutorials and videos to fully understand different variable types in C# in order to implement physics functions correctly in the experiment.

3. SOLUTION

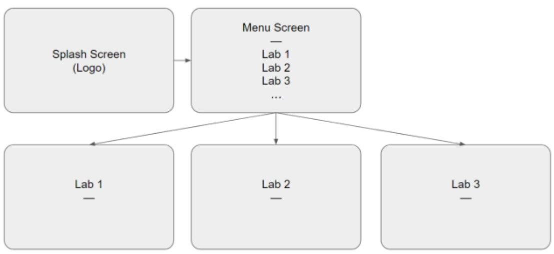

Figure 1. Overview of the Virtual Lab

The immersive educational platform for physics lab is designed by using C# with Unity where the C# supports all the features and operations happening in the lab, and the application of Unity creates a 3D virtual world to pull users into the immersive learning environment. The whole design of the virtual physics lab is broken into three big sections (Figure 1). The first section is the interface when users open the application where they will be required to press the open button to join the menu screen for the lab selection. The second section is the main menu where users are free to choose any lab to start with, the current implementation plan consists of three different labs. Once users have selected one of the three labs, they will join the virtual lab room to test and operate the corresponding experiment. The third section is the lab room which contains all the labs where users have the ability to switch between the labs. For example, after the users have finished the first lab experiment, they are free to move the character around the lab room. Each lab has its own desk to do the experiment, so users can walk to the next desk to do the other labs. It saves the extra steps of going back to the main menu to do the selection. Instead, it provides an immersive learning experiment where users have the same experience as the actual physics lab and make flexible choices while doing the labs. We are also planning to make quizzes for each lab which provide a short quiz when users have finished doing the lab [8]. By doing the quiz after the lab, it helps users to recall their memories while doing the experiment, making a deep impression of the details that happened in the lab. It is also an extra opportunity to practice and discover the weaknesses.

Figure 2. Starting Interface

First, the start of the user interface is designed as a magic style that sets off the theme of physics (Figure 2). The background is implemented as a dynamic background, and a book icon is placed at the center of the bottom. Once the book is pressed, it will lead users to the lab selection interface.

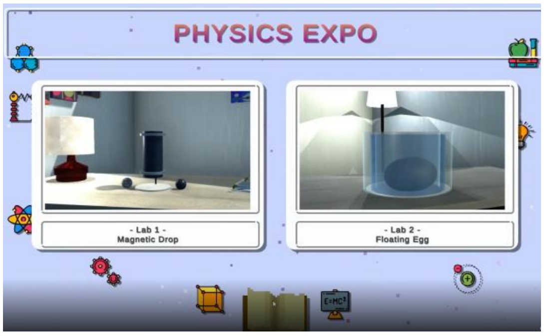

Figure 3. Lab Selection Interface

After pressing to open the book, the interface will change to lab selection where the background contains physical elements (Figure 3). There are two labs that have been implemented so far, users are free to choose any of them to start the lab. Each choice has an experiment picture, lab number, and lab name in order to help users to distinguish and make the correct choice. In the future, there will be more labs coming into the list, we are also planning to set different categories or folders to group labs based on topics. There will also be a search button or filter to support quick access to specific labs.

Figure 4. First View of Magnetic Drop Lab

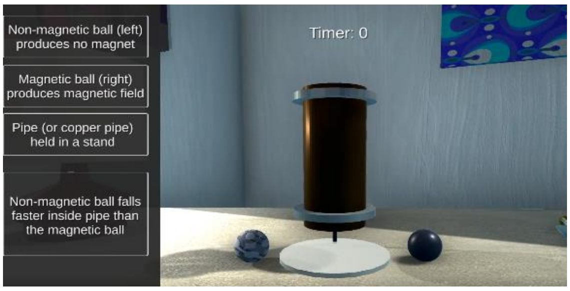

Figure 5. The Explanation of Magnetic Drop Lab

For example, if the user has selected "Lab 1: Magnetic Drop" to start the experiment, the user will be brought into a virtual lab room where he or she is free to move the camera and walk around the room. A piece of short instruction information will be provided on the screen that asks the user to "Press E to activate Magnetic Drop Lab" (Figure 4). After that, the screen will display an explanation of the materials and results of the experiment in order to provide a clear understanding of the goals for the current lab (Figure 5).

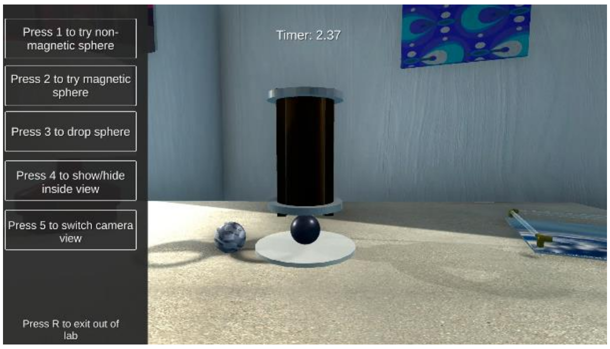

Figure 6. Front View of Magnetic Drop

Once the experiment starts, a list of operations is displayed on the left side of the screen (Figure 6). The user can press "1" to try a non-magnetic sphere. "2" to try the magnetic sphere, "3" to drop the sphere, "4" to show or hide inside view, "5" to switch camera view, and "R" to exit out of the current lab. When each drop has started, the timer will start to record the time that sphere will fall from top to bottom. Once a new sphere is switched, the timer will reset to 0 and start counting for a new round. This lab also supports different observations of the experiment where the inside view of the sphere can be shown or hidden. It provides a flexible experiment for observing the movement of the sphere within the object. In addition, a different angle of observation is also provided to the lab.

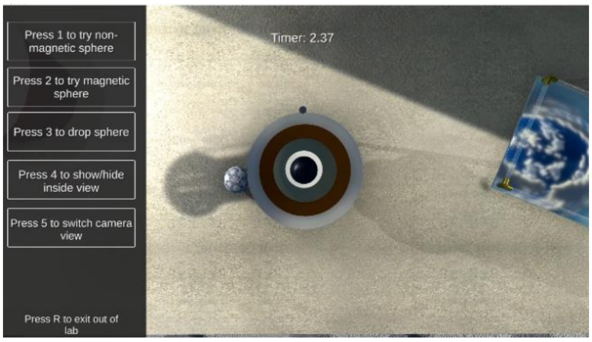

Figure 7. Top View of Magnetic Drop

After pressing “5” to switch the camera view, the observation angle will change to the top where the user can see the movement of the sphere vertically in the object (Figure 7). The interface is similar to the front view, and the user still has access to the operation list from the left of the screen. A timer is also shown on the top of the screen to record the time when the sphere reaches the bottom. By providing a different view of the lab, it supports users to enjoy the immersive learning experience where they are able to learn the experiment by observing it from different angles in order to discover any changes and patterns in the results.

Figure 8. View of the Lab Room

Once the user has finished the current lab, he or she is free to press “R” to exit the current lab. The user can move to the other lab desk for a new experiment (Figure 8). When they walk closer to the lab desk, the instruction information will display on the screen.

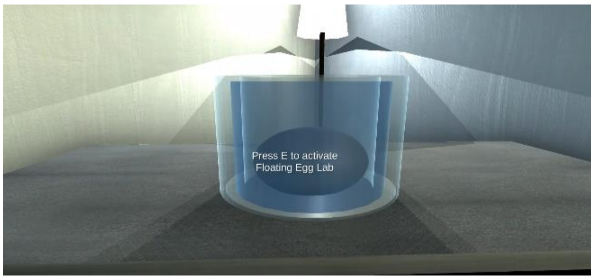

Figure 9. First View of Floating Egg

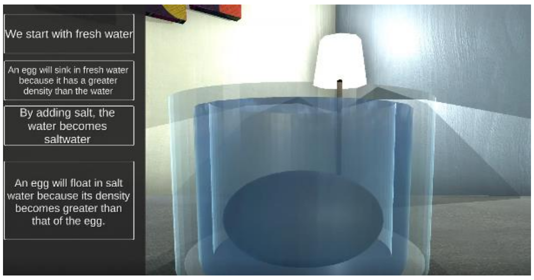

Figure 10. The Explanation of Floating Egg

When the user wants to do another lab in the lab room, they can walk close to the lab desk and press "E" to activate the lab. For example, if a user has finished Magnetic Drop Lab and wants to do Floating Egg Lab, he or she can start it by pressing "R" (Figure 9). After that, the explanation and instruction will display to the left of the screen in order to provide a clear mind of how the experiment would work (Figure 10).

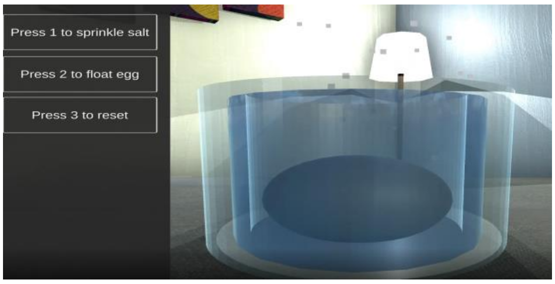

Figure 11. The Front View of Floating Egg #1

Once the Floating Egg experiment starts, it will provide an operation list from the left of the screen such as press "1" to sprinkle salt, press "2" to float the egg, and press "3" to reset. The action of adding salt is implemented as a dynamic action where the little white spots are the salts added to the water (Figure 11).

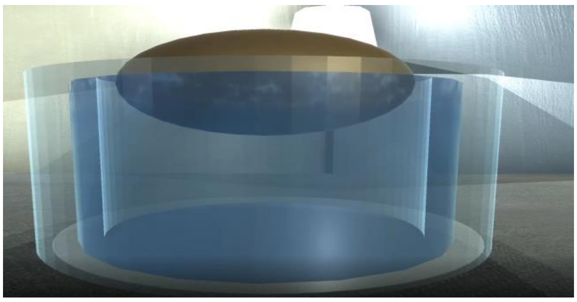

Figure 12. The Front View of Floating Egg #2

Because the salt is added to the water, the egg will float in the salted water since the density becomes greater than that of the egg (Figure 12). Instead, if the water is not salted, the egg will stay under the water all the time. The whole experiment is designed by dynamic reactions so that users are easier capture the changes in the lab.

4. EXPERIMENT

4.1. Experiment 1

In order to check the user experience within the virtual lab room, we have created a checklist that covers all the major operations that could happen while using the application. We will join the virtual lab as a user to test all the tasks that are listed in the checklist, making sure the features work in the good condition. By looking at Table 1 of the checklist, we have self-tested the camera movement, character movement, lab instruction, timer, different angle of observation, exit button, switch between labs and change mouse sensitivity. The major operations and functionalities work great and reflect good feedback while testing the whole application. However, we also realize a few issues with the beginning instructions which might cause new users not able to get familiar with the controls. For example, once the user has successfully joined the virtual lab room, there are no tips or hints about how they can interact with the character. By discussing this issue, we have decided to add a list of buttons with their functionalities along to the side of the screen such as buttons “W” moving forward, “S” moving backward, “A” moving to the left, and “D” moving to the right. In this case, not only the new users will have a clear mind of how they could control the virtual character, but also it reminds the returned users of how they could interact with the application.

Table 1. Experiment 1 - Check List

Operations	Results
Camera Movement	✅
Character Movement	✅
Lab Instruction Displayed	✅
Timer	✅
Different Angle of Observation	✅
Press “R” to Exit Current Lab	✅
Switch Lab	✅
Change Mouse Sensitive	✅

By considering the accuracy of the results from the virtual lab, we have created the second experiment to evaluate and compare both labs from the virtual lab and real life. We set two separate teams Team 1 recorded lab results from the virtual physics lab, and Team 2 recorded lab results from the real-life lab. By doing this, it supports the virtual labs to have the same authenticity and accuracy as people doing the labs in the real lab. First, it proves the results are trustable while doing the labs in a virtual way. Second, it gains feedback from the results in order to determine any mistakes in the calculation or logic implementation. Both Team 1 and Team 2 tested two labs which were Magnetic Drop and Floating Egg, and we compared the results on the same table (Table 2) [10]. By looking at the table, when we compare the results of Magnetic Drop from Team 1 and Team 2, the result looks accurate since the Non-magnetic Sphere takes a shorter time than the Magnetic Sphere. Although the time between Team 1 and Team 2 has a deviation of 0.01-0.02s, it does not affect the result of the experiment where the logic of the lab is still correct. The lab of Floating Egg also has the accurate result where Team 1 and Team 2 both test the condition of an egg in salted water and clean water. The egg is floated with salted water in both virtual and real-life lab, and the egg with clear water is not floated. Comparing the results from the virtual lab and real-life lab plays an important role to prove the consistency of the results, and it’s also a good behavior to check the deviation between the virtual lab and real life. This kind of evaluation could help us to minimize deviation and mistakes while implementing new labs in the future [9].

Table 2. Team 1 vs Team 2

Tasks	Team 1: Virtual Lab	Team 2: Real Life Lab
Magnetic Drop: Non-magnetic Sphere	Time: 0.58s	Time: 0.56s
Magnetic Drop: Magnetic Sphere	Time: 2.37s	Time: 2.36s
Floating Egg: With Salted Water	Egg Floated	Egg Floated
Floating Egg: With Water	Egg Not Floated	Egg Not Floated

5. RELATED WORK

Hamed, G. et al mentioned an important key concept of using the virtual learning lab where students could have a flexible learning environment [11]. For example, students are free to do experiments at home, school, computer lab, etc. The virtual learning environment brings benefits to both time management and flexibility. It is also the main reason why we designed this virtual physics lab to support students doing or testing labs at anyplace and anytime. Therefore, the immersive feeling becomes a necessary demand for students to enjoy learning.

M Erfan et al introduced an Android application of Physics Virtual Lab which provides a mobile platform for students [12]. This idea solved the issue when students do not have the laptop or desktop but they can still do physics labs on smartphones. By learning the idea from this research, it makes me have the action to implement our application as an Appin the future in order to provide a wide and convenient user experience. Because the current system is only playable on laptop or desktop, it restricts some students who are willing to do virtual physics labs without a computer.

Nindha Ayu B. et al researched on how virtual physics labs affect students' study by collecting information from students using surveys [13]. It’s a really good way to receive feedback from users, and the feedback would be the best information to improve the application in different aspects such as adding a new physics experiment, implementing a new feature, and changing the user interaction. By reading this research, it reminds me the importance of making quizzes for each lab. Since the quizzes section is still in progress, we might need to reconsider the format of the quiz after each lab. For example, the quiz can contain 10 questions, the first 9 questions ask about the knowledge from the lab, and the last question is a feedback question where users are allowed to put any feedback about the lab or any improvements that they recommend to us.

6. CONCLUSIONS

In this application, we have designed a game-based interactive and immersive educational platform for physics lab learning. We have designed the whole lab by using C# with a 3D Game Engine [14]. It provides an immersive feeling like doing the labs in real life. Users are being taken into a virtual physics lab where different experiments are implemented to the application. A virtual character is controlled by users to move around the lab room where each lab has its own desk to do the experiment. Users will first see an overall instruction for that specific lab, and they can start observing the experiment by following the different inputs or commands. Some of the experiments are supporting different angle observations so that it provides a great experience to do the observation in a special view in order to discover more details of it. Based on the evaluations, the virtual lab provides the same accurate results as real-life, and it is more effective for users who want to use the labs outside of the school or lab room. They can practice and exercise in the labs at any place and any time, and they can refer to the labs while doing the reports or homework. Since the quiz section is still in progress, it might limit users who want to ask questions right after the experiments. Once the quiz section is ready for users, the virtual physics lab will be more comprehensive as a practice tool, and users can check themselves by answering the quiz questions [15]. It not only helps them to recall the images of the lab but also supports them to remember details in mind. In the future, we will keep working hard to implement more labs into the application in order to provide a diverse lab to all grades of students. Since the current application only supports a laptop or desktop, our next plan is to publish the application as a small application as well so that users are more flexible in using the application without computer limitations.

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