

A UNITY MICROSCOPE SIMULATION TO HELP STUDENTS GET MORE ACCESS TO LAB EQUIPMENT ONLINE DURING COVID-19 PANDEMIC

Kaiwen Chen¹ and Yu Sun²

¹Santa Margarita Catholic High School, 22062 Antonio Pkwy,
Rancho Santa Margarita, CA 92688

²California State Polytechnic University, Pomona,
CA, 91768, Irvine, CA 92620

ABSTRACT

Something that still remains an issue to this day is how students and other individuals can become educated in matters that are generally taught in person and are difficult to translate to an online environment in particular [5]. In particular, teaching how to operate lab equipment without having hands-on experience is incredibly difficult. With the COVID-19 pandemic, the need for sufficient online learning materials and tools has become much greater in recent years [6]. To resolve this issue, a simulation was made in Unity that aims to educate its users on how to work with a microscope [7]. Sliders are provided in the simulation to control the X-axis, Y-axis, Z-axis, and focus. The simulation was tested for its effectiveness by gathering fifteen participants to download and test the simulation, then asking each participant to fill out a survey. In the survey, the participants graded the educational value and convenience of using the application on a scale from one to ten, and they were encouraged to leave any other feedback in a free-response section of the survey [8]. Results indicated that the general public would find this simulation practical in daily life, as participants generally rated the simulation as both educational and convenient to use.

KEYWORDS

Simulation, Microscope, Unity.

1. INTRODUCTION

Microscopes have been an important invention that has been widely used throughout history. The concept started with two lenses placed on opposite sides of the tube, and Galileo Galilei perfected the invention in 1609. When using microscopes, we can observe the world much closer and through a perspective that would not have been possible with the naked human eye. In particular, microscopes have paved the way for numerous advancements in science and medicine. With the help of microscopes, humanity has been able to discover smaller forms of life such as bacteria, viruses, fungi, and other microorganisms, and doctors have been able to identify the source of illnesses and even develop cures for illnesses [1]. With its impact on our society, the ability to use them can be crucial to those who wish to pursue careers in relevant fields.

The topic of how to use microscopes is significant because many students use them, whether they are taking major courses in college or doing a lab in a middle school science class. Whenever

microscopes had to be used, they were commonly done so within a classroom or laboratory setting, in which students and researchers would be able to handle the microscopes physically. However, after the COVID-19 pandemic hit, using physical microscopes became much more difficult [9]. And social distancing guidelines made it so that in-person instruction can be quite limited. With the rapid development of technology in recent years, a new popular path can be opened for teaching individuals how to operate a microscope.

There are currently many guides on how to operate a microscope. They exist in mostly text or video form, and many of them are easily accessible through the internet. Simulations that teach users the intricacies of using a microscope are also present, which can give visual learners an easier time understanding what to do. The way that is believed to be best for students' understanding is to have a hands-on demonstration of how to use the microscope and have the students follow along with a physical microscope. Depending on what the situation calls for, different methods of teaching may have their advantages and be preferable. Unfortunately, these methods also come with fairly significant drawbacks. With text-based guides on how to use microscopes, the biggest limitation is being able to visualize the instructions and apply them in a lab environment. Video-based guides can solve this issue, but what both guides lack is the involvement of the learners. This concept of active learning is applied in simulations [10]. Unfortunately, many simulations suffer from being either too simple or too complex. Simulations can simplify the action of using a microscope far too much when they only require a click of a button. Others may require the user to make so many complicated motions with the microscope and show so many numbers on the screen that the details detract from the main points. Furthermore, the graphics of some older simulations may be jarring and ward away potential users that have been accustomed to better and cleaner graphics. The method of getting hands-on experience with a physical microscope may no longer be feasible in recent times, when concerns over public health and distance may restrict people to only using online resources. With advancements in technology, a new method may be able to address the downsides of previously used methods.

A Unity game was created that was meant to educate its players on how to properly use a microscope in a lab environment [11]. The primary features of this game are sliders that the player is able to control using the mouse. There are four sliders in the simulation: the first one controls the X-axis, the second one controls the Y-axis, the third one controls the Z-axis, and the final one controls the focus. The X-axis determines how far to the left or to the right the image is shifted, and the Z-axis determines how far above or below the image is shifted. The Y-axis determines how closely the image is zoomed in. Finally, the focus slider will only allow the image to show up clearly on the microscope if the focus value is within a certain interval. Otherwise, the image will appear blurry.

Unlike guides on how to operate a microscope, the method of using a simulation is much more interactive and may allow for deeper understanding. Looking at text or a video of how to use a microscope may not let the concepts stick in people's minds as well as playing an active role in their own learning. While this simulation may be similar to other simulations, it also does its best to strike the perfect balance between being easy to use and understand and being educational.

The method we used to prove the effectiveness of the microscope simulation is by creating a survey on Google Forms. The Google Forms would have two questions: "How educational was this simulation?" and "How convenient was this simulation to use?". The first question asks the participants how much understanding and knowledge they can derive from the simulation, and the second question asks the participants how well the knowledge can be absorbed by the individuals that use them in a timely manner. Both of these qualities would be vital to the success of the simulation, as high scores in both would indicate that the general public would deem the

simulation worthy of use, whether it be in a classroom setting or at an individual's own leisure. At the bottom of the survey, an optional free-response section would be available for the participants to send any custom feedback that they may have about the simulation.

Fifteen participants will be gathered, and each of them would be asked to download the ZIP file that includes the Unity simulation. They would be instructed to unzip the file, then run the simulation inside the unzipped folder. From there, the participants would spend at least one minute testing each of the sliders inside of the simulation and understanding how the microscope works as a whole. After they are finished using the simulation, they would be provided with a link to the Google Forms survey. Whatever responses the participants gave would be recorded in a linked Google Sheets table, including the feedback in the optional free-response section at the bottom of the survey.

The remainder of the paper will be divided into five sections, which will be labeled with the numbers 2 through 6. Section 2 describes the hurdles that had to be overcome when coming up with ideas for the simulation and experimenting on the simulation. Section 3 offers an explanation for how the simulation as a whole, as well as specific sections of the simulation, was implemented. Section 4 brings up how effective the simulation is using a survey that tests for important qualities that are desirable for users, and Section 5 introduces related works and how they compare to this work. The final section, Section 6, provides a conclusion that includes the summary of the simulation, some current limitations to the application, and what can be done in the future to address these limitations.

2. CHALLENGES

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

2.1. How education regarding science labs was limited by the COVID-19 pandemic

The problem to be addressed was how education regarding science labs was limited by the COVID-19 pandemic, leaving many classes only available online. Unfortunately, bringing science labs to an online environment is a more difficult transition than some other classes, as lab equipment that students would normally be able to get a hands-on experience with would no longer be accessible. When searching for the most common lab equipment that students would use, the microscope was consistently regarded as a useful and popular tool in modern science education. A comprehensive and well-written guide seemed like a good idea at first, but such a solution would not be able to emulate the active learning that students would be able to attain by directly operating a microscope. The next idea that was eventually implemented as the final solution was to create a simulation that could educate users on how to utilize a microscope.

2.2. How exactly to make the simulation

After figuring out what to make to address the issue of students having a lack of access to lab equipment, the issue of how exactly to make the simulation arose. There are several different kinds of simulations of microscopes online, with some that can even simulate multiple types of microscopes. To stand out from the others, the original plan was to make something that could provide the history of microscopes and other various information regarding microscopes that other simulations might not have. However, after envisioning the final product, such a feature might be overwhelming and might even be seen as irrelevant for users that are new to operating microscopes and are only using the simulation for the sole purpose of understanding how to use a microscope. With this in mind, the implementation of the simulation was made to be as easy to

understand and clear as possible to use, which would allow the target demographic of students or other individuals who have never used microscopes before to absorb the information in a much more efficient manner.

2.3. Experiments for the microscope simulation

The final challenge was coming up with experiments for the microscope simulation. Since the microscope is simple, it is difficult to test the simulation for how accurate it is. The only features to test within the simulation are the sliders that control the X-axis, the Y-axis, the Z-axis, and the focus. Therefore, a different form of experimentation was needed. After some brainstorming, the path of experimentation that seemed best was surveying participants and asking them to try the simulation. The survey would be split into two main sections, which are how educational it is and how convenient it is to use. Participants would be given the option to rate each section on a scale from one to ten. These sections would be crucial for our results, as having positive scores in both sections would mean that the simulation would likely be practical as a tool to be used by the general public.

3. SOLUTION

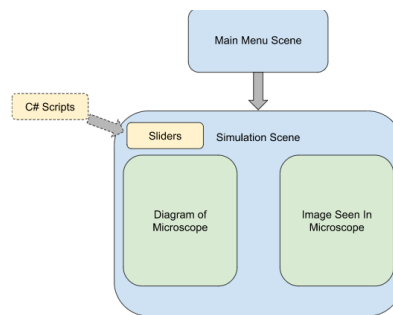


Figure 1. Overview of the solution

The Unity microscope simulation has two main scenes. The first scene is the main menu screen, in which the user is met with the title “Microscope” and a button labeled “Start” right below the title. To proceed with the next screen, the user will click the start button, which will transfer the simulation to the second scene. In this scene, an image of a microscope can be seen on the left side of the screen, and the image that can be seen through the microscope is present on the right side of the screen. On the top left of the screen, four sliders are available for the user to interact with. The first slider is the X-axis, and adjusting the X-axis value causes the stage of the microscope to move left and right in the diagram of the microscope on the left side of the screen. The image that can be seen through the diagram of the microscope on the right side of the screen is shifted horizontally. The second slider is the Y-axis, in which adjusting the Y-axis value moves the microscope stage up and down. The image seen from the microscope zooms in when the stage is moved up and zooms out when the stage is moved down. The Z-axis slider moves the stage forward and backward, and the image in the microscope shifts vertically to account for this change. Finally, the focus slider makes it so the image in the microscope shows up clearly when at a certain interval of values, but shows up as blurry for all other values. The functionality of the simulation is implemented using scripts written in the C# programming language [15].

In order to switch from the main menu scene to the simulation scene, a button is placed in the main menu scene. When the user presses the button, the button is able to transfer to the second

scene because the button was assigned a C# script. In this script, the SceneManager called the load scene function with the desired scene to be switched to in the argument of the function. As C# scripts provide much of the functionality in many Unity games and applications, this is a common way to perform the task of switching scenes.

The C# scripts play more of a crucial role in the simulation scene. The four sliders that are present control the X-axis, Y-axis, Z-axis and focus. All of these sliders have different effects on the image that can be seen through the microscope, and the first three sliders control the diagram of the microscope. The sliders in the simulation were created using the built-in slider element that can be selected from the user interface section of Unity. Just like with the button that transfers scenes, the sliders also have a script attached to them. The script controlling the X-axis slider controls both the stage of the microscope diagram and the image seen through the microscope as two separate tasks. The slider for the X-axis is directly linked to the position of the stage, which changes the X-axis of the stage object depending on the value of the X-axis slider. The X-axis of the image through the microscope is also shifted, which made the implementation of this slider surprisingly convenient. The same procedure is applied to the Z-axis. When it comes to the Y-axis, the script causes the stage to move up as the slider is moved from left to right. To match the stage moving up, the image seen through the microscope becomes zoomed in the farther the value is moved right along the slider. For the script controlling the focus slider, the diagram of the microscope does not change at all no matter what value the focus is set to. Rather, only the image seen through the microscope is affected. When the user first enters the simulation scene, the image appears blurry, as the focus slider is set all the way to the left. However, the only way to make the image appear clear in the simulation is to move the slider somewhere near the middle. This is performed by using a blur effect. When images are displayed in Unity, the quality of the image will be completely clear and unblurred by default. However, the script is coded so that the image's blur value is set to zero as long as the focus value resides within a certain interval, then the blur value becomes greater the farther the focus value is from that interval.

```
// Update is called once per frame
void Update()
{
    float x = startPosition.x;
    float y = startPosition.y;
    float z = startPosition.z;

    if (xSlider != null)
    {
        x = (startPosition.x - xlimit / 2) + xSlider.value * xlimit;
    }
    if (ySlider != null)
    {
        y = startPosition.y + ySlider.value * heightlimit;
    }
    if (zSlider != null)
    {
        z = (startPosition.z - zlimit / 2) + zSlider.value * zlimit;
    }

    gameObject.transform.position = new Vector3(x, y, z);
}
```

Figure 2. Screenshot of code 1

```

public void moveforwardBack(float value)
{
    value -= 0.5f;
    if (backgroundImage)
    {
        Vector3 pos = backgroundImage.localPosition;
        pos.y = value * backgroundSpeed;
        backgroundImage.localPosition = pos;
    }
}

public void movelDown(float value)
{
    value = 1 - value;
    if (backgroundImage)
    {
        float scalingFactor = 1 - (value * backgroundScalingFactor);
        backgroundImage.localScale = Vector3.one * scalingFactor;
    }
}

```

Figure 3. Capture Device Screenshot

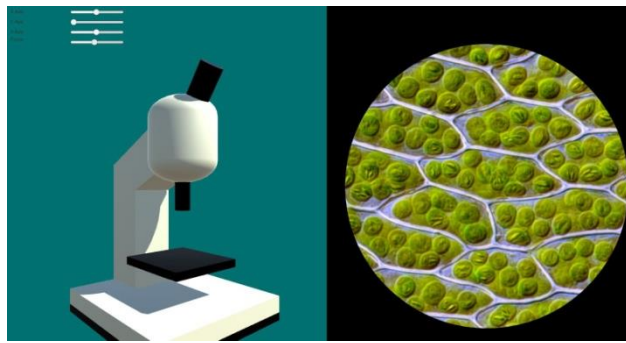


Figure 4. Image through microscope 1

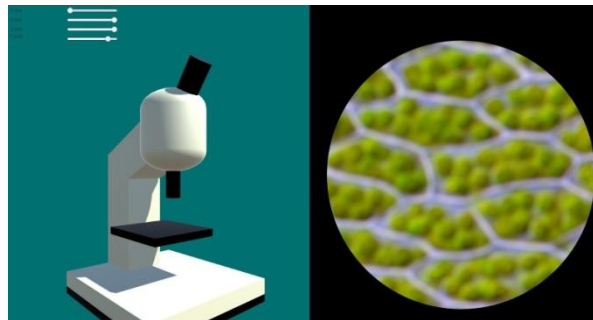


Figure 5. Image through microscope 2

4. EXPERIMENT

4.1. Experiment 1

The experiment that was used to test the effectiveness of the microscope simulation was a survey that was created in Google Forms. First, the participants would download a ZIP file, unzip the file, and run the Unity simulation from inside the folder. The participants would then spend at least one minute fiddling with the sliders and examining how changing certain values affects the position and image quality of the image and the stage of the microscope. After the participants are done, they would answer the first question in the Google Forms survey about how educational they felt the simulation was, which was recorded on a scale from one to ten. Since there are

fifteen participants taking the survey, there is a large enough sample size to account for variability.

Participant Number	Educational Value Rating of Simulation
1	10
2	9
3	9
4	5
5	8
6	7
7	8
8	9
9	8
10	10
11	9
12	9
13	7
14	8
15	7
Average	8.4

Figure 6. Table of participant number and education value rate

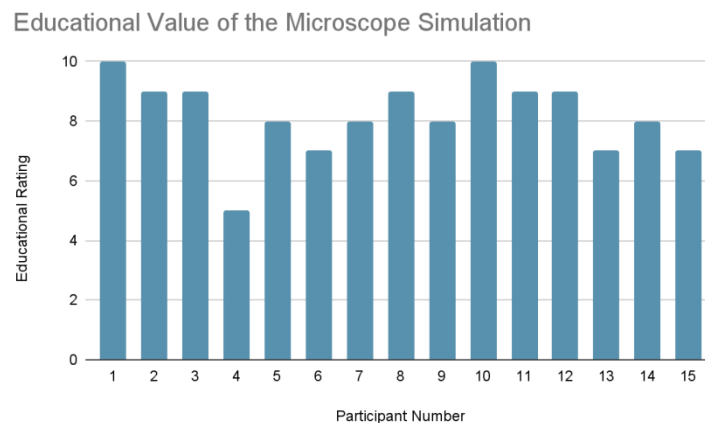


Figure 7. Graph of educational value of the microscope simulation

According to the results of the participants' perceived educational value of the simulation, it appears that the educational value ratings were fairly high. With the exception of one of the ratings at a 5, the rest of the ratings were 7 or above. Such results could signify that the participants were pleased with how much knowledge they received when using the simulation. Some feedback that participants sent stated that the implementation of the sliders in the simulation was well-made, as the sliders captured the feeling of having to use "guesswork" that people would experience when turning the knobs on an actual microscope and using trial and error to eventually get the best view from the microscope. However, two pieces of feedback also indicated that the coarse adjustment knob and the fine adjustment knob that are usually present on microscopes could have been emphasized more, and separate sliders to represent each knob could have been more informative.

4.2. Experiment 2

The second question in the same Google Forms survey asked how convenient using the simulation was. To keep the style consistent throughout the survey, a scale from one to ten was also used to record the results. At the end of the survey, an optional free-response section was provided to the participants. This would allow the participants more freedom to express their thoughts about the simulation and share more valuable insight that would not be possible with the previous two questions. The measurement for the convenience of the application was also not altered significantly by variability, as the sample size of fifteen would still be enough to mitigate its effects.

Participant Number	Convenience Rating of Simulation
1	10
2	8
3	9
4	6
5	9
6	7
7	9
8	10
9	8
10	10
11	8
12	9
13	8
14	8
15	9
Average	8.53

Figure 8. Table of participant number and convenience rating

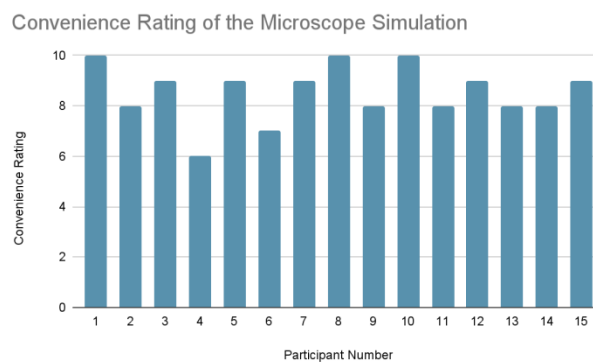


Figure 9. Graph of convenience rating of the microscope simulation

The results regarding the convenience of the microscope simulation indicate that the simulation is effective at helping its users absorb knowledge more easily. Three participants rated the convenience a perfect score of 10, and all of the ratings were 6 or above. Furthermore, an average result of 8.53 means that participants were generally very satisfied with how user-friendly the simulation is. The vast majority of participants who left feedback reported that the simulation was incredibly simple and easy to use, which allowed for a more convenient and enjoyable time learning with the simulation. The user interface was also generally praised by the participants for

its clean and minimal aesthetic. On the other hand, one participant also noted that the concept of the focus only reaching maximum image sharpness at a certain interval could be confusing to new users, and there should be at least some indicator or note that informs the users of this.

In the first experiment, the vast majority of the participants believed the implementation of the microscope simulation made sense and provided accurate information regarding how a microscope would work. As the participants are a subset of the general public, it is believed that the general public would likely find this to be educational for both students and other curious individuals.

With the results of the second experiment, it appears that the general public would also find the simulation to be very intuitive and convenient to use. With both qualities of the simulation being rated very highly, the simulation seems to be a valuable and helpful tool overall that can improve the learning process when it comes to using a microscope. These results were expected, as the simulation was specifically designed to optimize the learning of users who have never had experience operating a microscope before. Therefore, it could be concluded that this simulation has been a success so far.

5. RELATED WORK

One article reports on the use of an Arduino as a piece of lab equipment that can take on multiple roles within a lab environment, which is possible by loading scripts onto the board's memory. The Arduino is significant because it is more affordable and portable than dedicated hardware [2]. Both the Arduino article and this work mention the usage of lab equipment and the effectiveness of implementations. While the Arduino article focuses on the physical implementation of lab equipment, this work emphasizes the implementation of a microscope through software that can act as an online learning tool for the general public.

Another work states that the use of algorithms and computations can be integrated into a microscope in order to create a more advanced microscope with improved accuracy. Recent improvements in simulation speed can allow the viewing of important biochemical processes such as protein folding and membrane transport in milliseconds [3]. The related work and this work both share the topic of simulations involving microscopes. In particular, the related work offers an in-depth view of how computational microscopes can improve the field of science through various examples. On the other hand, this work involves the creation of a simulation of a traditional optical microscope and how effective it is at educating the general public.

A third related work covers the history of the optical microscope in cell biology and medicine. Only with the large magnification of microscopes, along with proper contrast and resolution, have we been able to see cells and their components. Recently, light microscopy has advanced to the point that live cell imaging is possible [4]. This work is similar to the related work because the topics of both works are related to optical microscopes. However, while the related work emphasizes how the optical microscope has been improved and utilized in making discoveries for cell biology, this work places its focus on the creation and experimentation of an optical microscope simulation.

6. CONCLUSIONS

In light of the COVID-19 pandemic and the difficulty of learning information from online science labs that would be best done in person, a simulation was created to educate the general public on how to operate a microscope [14]. The simulation features four sliders, which each

affects the image shown by the microscope in a different way. The X-axis and the Z-axis control how far the image in the microscope is shifted in a certain direction, the Y-axis controls how zoomed in the image in the microscope is, and the focus controls how clear the image appears in the microscope. The simulation was designed to teach students and other members of the general public the core concepts of how to use a microscope in a simple and digestible form.

The experiment that was performed was a survey that gauged how useful the simulation would be if it was released to the general public. Fifteen participants were asked to download the Unity simulation, use the simulation for at least one minute, then submit their responses on a Google Forms survey as to how educational the simulation was and how convenient the simulation was to use on a scale from one to ten. The responses were then recorded into a Google Sheets table that was linked to the Google Forms survey [13]. According to the results, the simulation was effective at providing some educational value to its users as well as offering a clean and intuitive user interface for the users to work with. The feedback indicated that the ease of use was what the participants generally appreciated the most about the simulation.

A current limitation of the simulation is that the simulation only educates the user on how to use a microscope. However, in a lab environment, microscopes are not the only instruments that are used to conduct research or perform experiments; many others are used as well, such as volumetric flasks and spring balances. Although the simulation serves its current purpose fairly well, the scope of the simulation is limited by its sole topic of how to use a microscope. Ideally, the simulation could be expanded to become a more general-purpose tool that could offer its users more knowledge about various sets of lab equipment.

To address this limitation, some work regarding the simulation that is planned for the near future is adding some of the most common lab instruments [12]. In the main menu of the screen, rather than just having a button to start the simulation, there would be multiple buttons that correspond to each instrument. Furthermore, the option to go back to the main menu would be added as well, in case the users decide that they have tried a certain instrument enough and want to try another one.

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