GNG1103 F
Group 11

Project Deliverable H (COVID-19)
Final Prototype Update

This deliverable is quite different in comparison to the other prototyping updates from past weeks. Amid the recent COVID-19 outbreak, the design team has been forced to work remotely and practice “social-distancing.” These conditions have made it quite difficult for the design team to continue working on the VR system. Despite the team’s efforts to complete the project remotely, with the help of *Slack* and *Zoom*, the product could not have been completed.

For this deliverable, the design team will be providing in-depth descriptions of the final state of the uncompleted product. Countless screenshots and subsystem descriptions will be used to outline the progress that had been made before the design team was unable to continue working.

As well, the “next steps” that would have been taken to complete the project will be included in this deliverable. These steps describe the procedure that would have been followed if the team was not working remotely and had access to the proper facilities. The tasks that remained will be displayed in a Gantt Chart. This will make it easier to display the time constraints, interdependencies, and owner of the tasks.

Despite the unexpected obstacle that the design team faces, the progress and projected timeline for the project must be provided. It is crucial to include this information in case other students or professionals wish to continue the project. It would save a lot of time and money if detailed descriptions and screenshots were made available.

Work Done for Prototype III

As stated, the design team was unable to fully complete the VR system due to the abrupt COVID-19 outbreak. Despite this obstacle and the lack of facilities, substantial work was still done to complete as much of the product as possible. Several features were improved and added for the final prototype, even though the design team was incapable of testing them without the necessary resources.

The subsystems that were improved or added to the final prototype are the following:

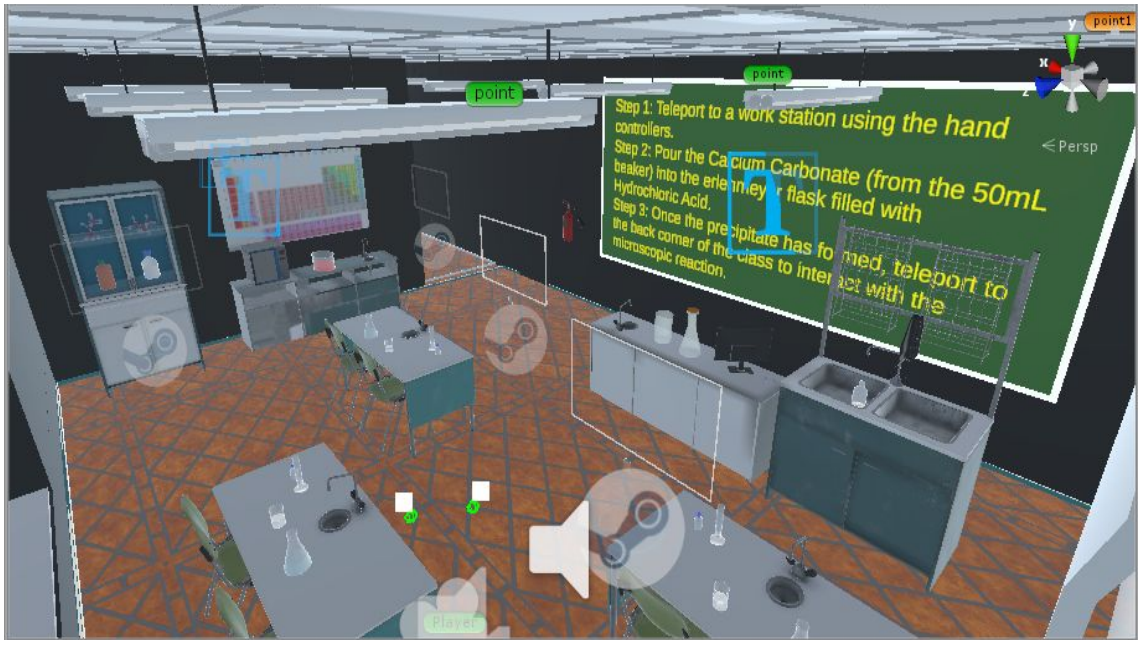
- Main Player and Teleportation
- Quiz Room
- Reaction Room
- Molecular Models and Collision Paths
- Macroscopic Reaction
- Cosmetics and Other Ergonomic Features

Prototyping and Testing the Main Player and Teleportation

To have the user move around the lab environment and grab objects, a “player” in *Unity* must be created. For the user to interact with the software, it is crucial that they can relocate. To do this, *Unity* has teleportation scripts, which allow the player to choose their next location in the environment.

These were crucial aspects of the final product because they allow the user to interact with the system and choose their next actions. Software interaction was a significant need of the client and it will make it easier for the student to learn organic chemistry.

Below is a screenshot of the final product with the player and teleportation points included. The *Steam* symbols represent the teleportation points that the user can use to move around the environment. The ‘ ’ symbol represents the player in the game, which provides the user with a first-person experience.



These aspects were created and implemented into the global system in roughly 2 hours. However, due to the lack of CEED facilities, more specifically the *Design Commons*, no testing was conducted. This means that the design team is uncertain whether these aspects are functional and accurate.

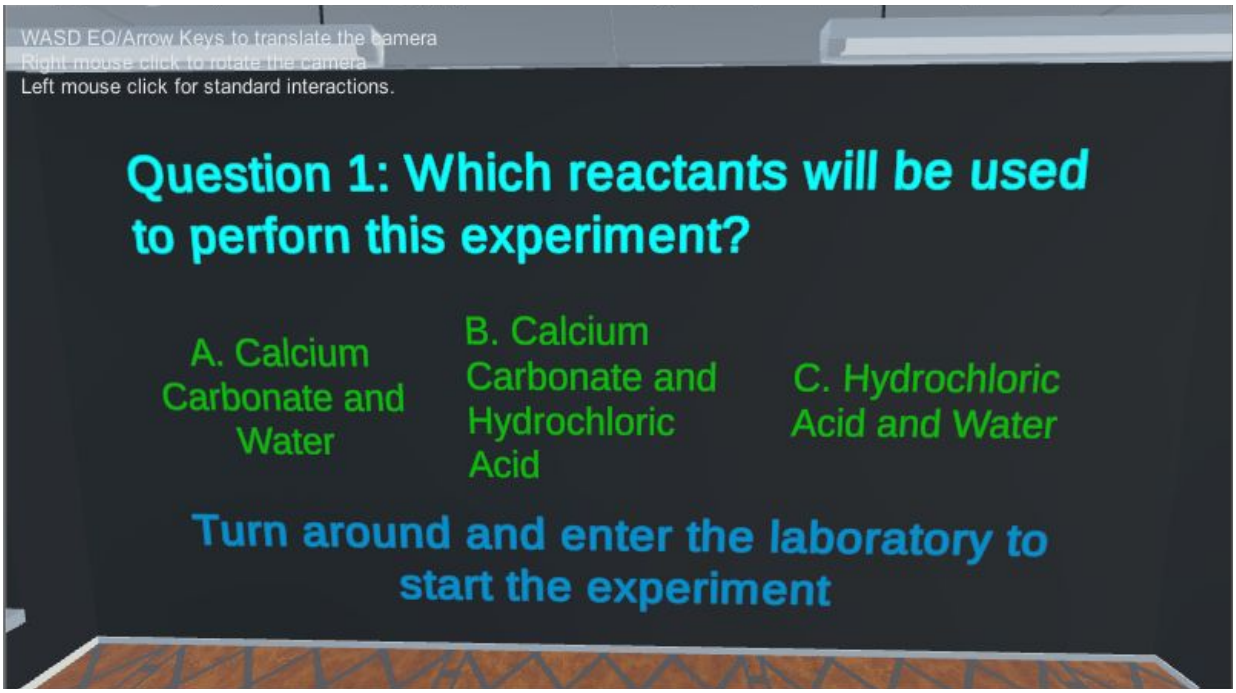
Prototyping and Testing the Quiz Room

The environment from Prototype II was improved with the addition of a new room, the quiz room.

The quiz room, also used as the entrance, is the place where the user does their pre-lab quiz. Once the user completes the quiz, they are instructed to turn around and enter the lab, where they will perform the experiment.

To build the quizzes, a *Unity* asset was purchased, and it was to be implemented into the global system. Unfortunately, *Unity 3D* no longer supports this asset, so the design team was not able to use it. The day that the *Design Commons* closed was the day that the team planned to work on the quizzes, so this aspect never got completed. Since the design team never had the chance to work on the quiz, text boxes were used in the quiz room to conceptualize the pre-lab quiz.

Below is a screenshot of the quiz room and a screenshot of the pre-lab quiz concept.



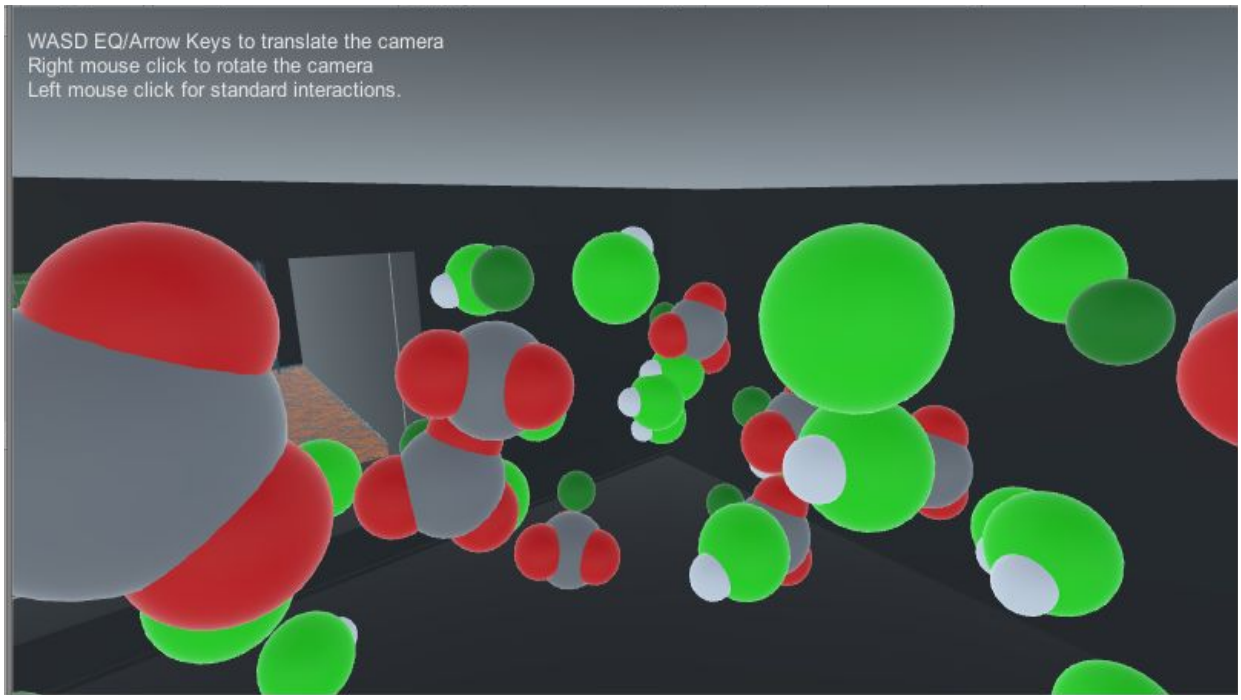
Testing the quiz room was simple. Using a PC and *Unity*, the design team ensured that the environment was accurate, and all assets were being displayed correctly. Since the pre-lab quiz was not completed, there was nothing to test, so the team ensured that the conceptual text boxes were displaying the correct information.

Prototyping and Testing the Reaction Room

The environment from Prototype II was once again improved with the addition of the reaction room.

This room, at the back corner of the lab, houses the molecular models and will contain their collision paths. This room allows the user to experience and interact with the microscopic reaction. Although it was easy to set up the room, it was difficult to execute the proper experience. The goal was to immerse the user in the reaction and surround them with chemical models. To do this, a teleportation area was added, allowing the user more freedom to move around and interact with the models.

Below is a screenshot of the reaction room within the global environment and a screenshot of what the user sees while standing in the reaction room.



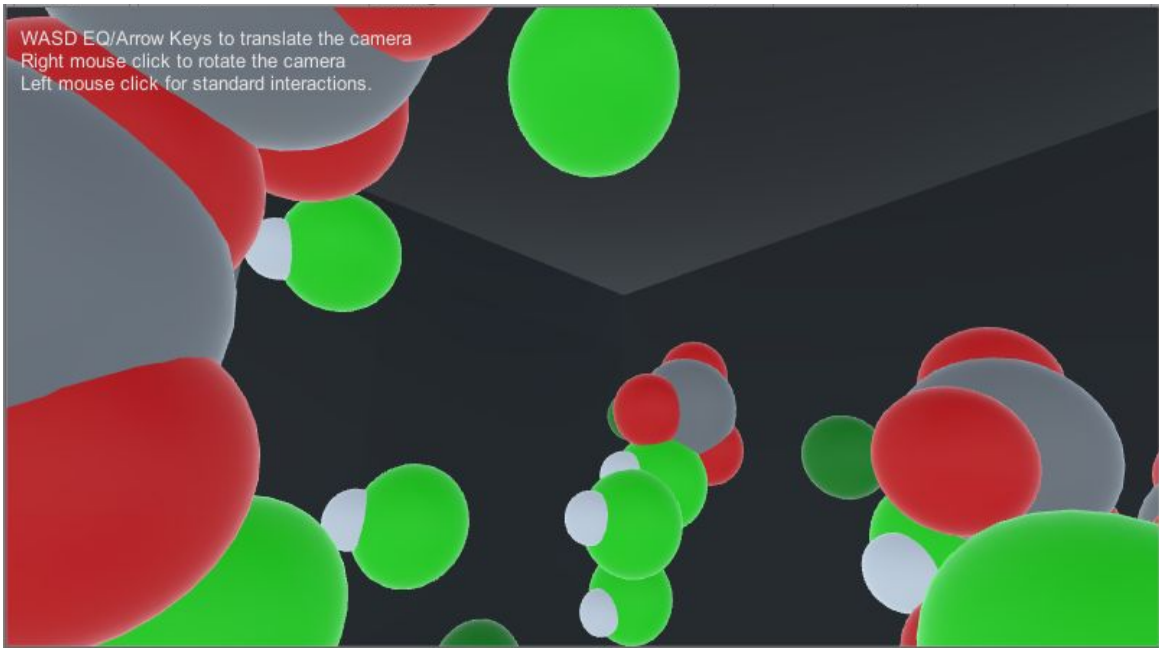
Once again, testing this room was very simple. The design team ensured that the room looks proper in comparison to the rest of the environment and that all aspects of the room were being displayed correctly. As well, the design team was unable to test the teleportation area since access to the VR headset and controllers were restricted due to COVID-19.

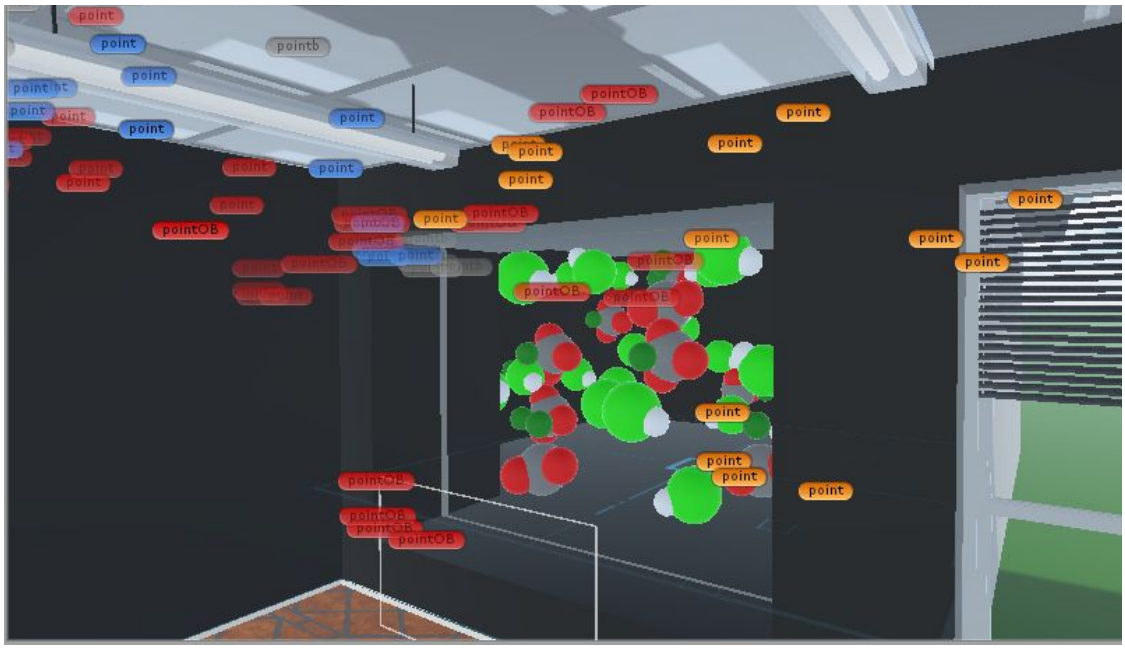
Prototyping and Testing the Molecular Models and Collision Paths

The microscopic reaction was created in its own file for the second prototype and was transferred to the environment for the final product. Therefore, all the movement scripts and collision points needed to be added as well. Once these files were transferred, the molecular models, along with their motion scripts, were added to the reaction room. Some minor adjustments needed to be made to the collision points, to ensure that the molecular models do not escape the reaction room.

After adding the models and their collision paths to the final product, the design team decided to alter the microscopic reaction script. While testing before the facility closure, the team found that the reaction timing was inaccurate. To fix this issue, a “switch” was added to the models’ scripts. The design team decided that when a student teleports to the reaction room, then the models would begin moving and colliding. This fixed the timing issue and made the microscopic reaction look more accurate.

Below is a screenshot of the molecules within the reaction room and a screenshot displaying all the collision points.





Testing was conducted on the microscopic reaction when it was in its own file using the VR headset and hand controllers. However, no tests were conducted on the reaction while being implemented into the global system. There should be no difference in molecular movement and collisions, but the design team has no way of knowing whether the “switch” works correctly.

Prototyping and Testing the Macroscopic Reaction

The macroscopic reaction was created for the final prototype, rather than its own file. This reaction will allow the user to pour the $CaCO_3$ solid into a flask containing HCl and observe a precipitate formation. “Grabbing” and “physics” scripts were added to the glassware involved in the macroscopic reaction to provide the students with more control. As well, since the students can initiate the chemical reaction, the software is more physically interactive, which was a significant need of the client.

Adding the macroscopic reaction to the global system was simple; only glassware and a few scripts needed to be added. The glassware kits were added to every lab bench, enabling students to choose their own path once again. Distinct colour solutions were also added to the glassware to help students distinguish the reactants and more effectively understand the reaction.

Below is a screenshot of the macroscopic reaction at its initial stage.

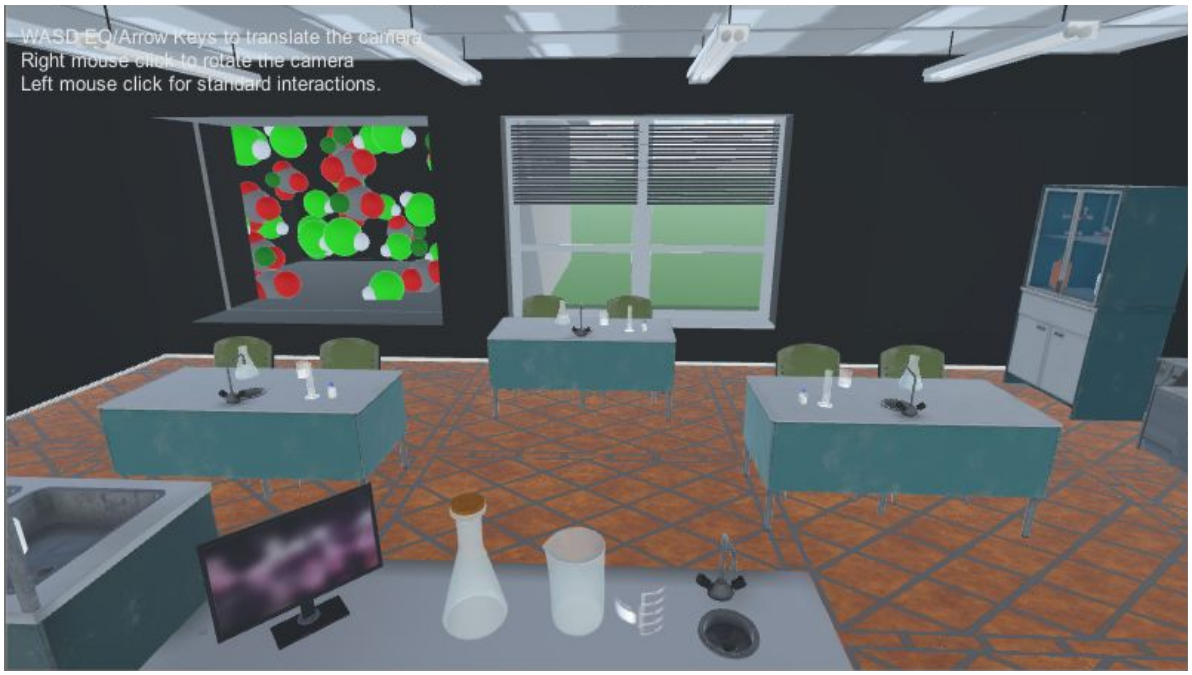
Since this reaction was added after the CEED facilities closed, the design team was unable to test the system. The design team does not have the hand controllers, which are needed to grab glassware and pour the solutions. Since the team can not initiate the reaction, there is no way of knowing whether the precipitate will form correctly for the macroscopic reaction.

Prototyping and Testing the Cosmetics and Other Ergonomic Features

Cosmetics and several intricate details were added to the final prototype as well. It was crucial to include these details (glassware, furniture, colour around the environment, etc.) to maximize user experience.

Around the global environment, fonts and colours were chosen to maximize visibility. Glassware and lab equipment were selected to make the environment more realistic. Furniture was added to make the lab look fuller, rather than just an empty room with one lab bench. Floor tiles, baseboards, and grass outside the lab are examples of some intricate details that were added to maximize user experience.

Below is a picture of the lab from behind the teacher's desk which itself includes accurate details.



Since this aspect of the global system is purely cosmetic, the testing was quite simple. The design team checked, using a PC, whether these details are accurate and being displayed properly.

Final Prototype Status Update

For this section, the design team will completely describe the final product and provide many pictures to fully document the prototype. This information would be given to the client to display the work that has been completed and how much of the final product remains unfinished. Despite the unforeseen circumstances, the design team was able to complete most of the product, as seen below.

Also included in this section is a full description of the final product's purpose and function. Ways in which the client and users would interact with the final prototype will also be provided. All this information would be provided to the client for further clarification on all the final product's capabilities.

Purpose and Function of the Final Prototype

The purpose of the final product is to teach organic chemistry to first-year students in a unique and creative way. The design team created a product that would allow students to physically interact with a chemical reaction. To accomplish this, the team generated a virtual reality system that permits users to immerse themselves in an organic chemistry reaction.

For the chemical reaction, the design team wanted to provide a unique experience that most students have never seen before. The team decided to create a macroscopic reaction and its microscopic interpretation, both of which the students can physically interact with. These two reaction interpretations will allow the users to see how changes on the macroscopic level (everyday life) can affect the atomic level. This unique chemical reaction, along with scientifically accurate chemistry will enable the student to acquire a whole new viewpoint of organic chemistry.

To ensure that the student's experience is accurate and realistic, the design team created a chemistry lab-like environment. This setting would be familiar to the users and generate a more authentic experience. The design team invested a lot of time and effort to maximize user experience; this was done with the hope of making students more comfortable with the unique product.

Client Interaction with the Final Prototype

The design team employed several ways that the client and users can interact with the final product. When the user first enters the VR environment, they are prompted with a pre-lab quiz. This quiz is meant to ensure that the students have prepared for the lab and completely understand the important aspects of the reactions. Since the team did not finish this subsystem, the user is unable to interact with it. Under better circumstances, the design team's goal was to allow the user to shoot an arrow or throw a ball at the correct answer. Once the quiz would be completed, the plan was for the student's grade to be posted inside the same room. The design team added all these interactive aspects of the pre-lab quiz to maximize user experience.

Next, once the student enters the “Main Room,” where the macroscopic reaction takes place, there are so many things to interact with. Firstly, teleportation points are placed all around the room, allowing the user to move around the environment and interact with different lab equipment. The user is then prompted to approach a lab bench and perform the macroscopic reaction. The students can grab and pour solutions from assorted chemistry glassware for this part of the VR experience. Once the user successfully performs the reaction, they can grab the Erlenmeyer Flask containing the final products. The student can then notice the precipitate that forms in the flask; this small detail displays the team’s commitment to realistic reactions. The design team added all these interactive elements to create an authentic organic chemistry experience for the students.

Lastly, the user is prompted to teleport, using the VR hand controllers, to the “Reaction Room.” This part of the environment contains the microscopic reaction and allows the student to immerse themselves in the molecular models and collisions. To enter the room, the students teleport onto the teleportation area; this area contains a script allowing the user to dictate when the reaction begins. Once the reaction begins, the user can grab and drag the models at any stage of the chemical process. The user can choose to grab a reactant, intermediate, or product. The design team chose to implement all these choices into the VR product because they allow students to make their own decisions, rather than forcing them to follow a fixed procedure.

The design team added all these elements to the final prototype so the client and organic chemistry students can physically interact with the product.

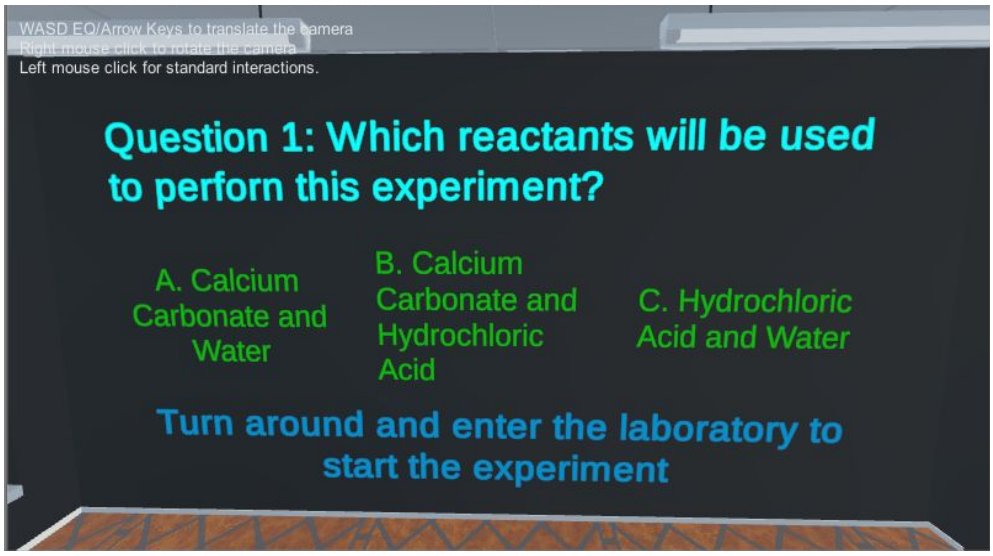
Final State of the Prototype

For this section, the design team will provide a complete analysis of the product and all its capabilities. As well, the team will give some insight into the effects that the COVID-19 outbreak has had on the creation of the final prototype. Pictures of the final product will also be included to help describe the main aspects of the design team’s project.

When the user first enters the environment, they are in the “Main Entrance / Quiz Room.” In this room, the user is greeted and prompted to begin the pre-lab quiz. The photos of the Quiz Room below help display the design team’s attention to detail and focus on user experience. The small things like text fonts and colour, along with window covers and baseboards, are what separates this product from similar ones on the market.


WASD EQ/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
Welcome
This game is brought to you by the VR Virtuosos
Turn around to start the pre-lab quiz
B. Calcium Carbonate and Hydrochloric Acid

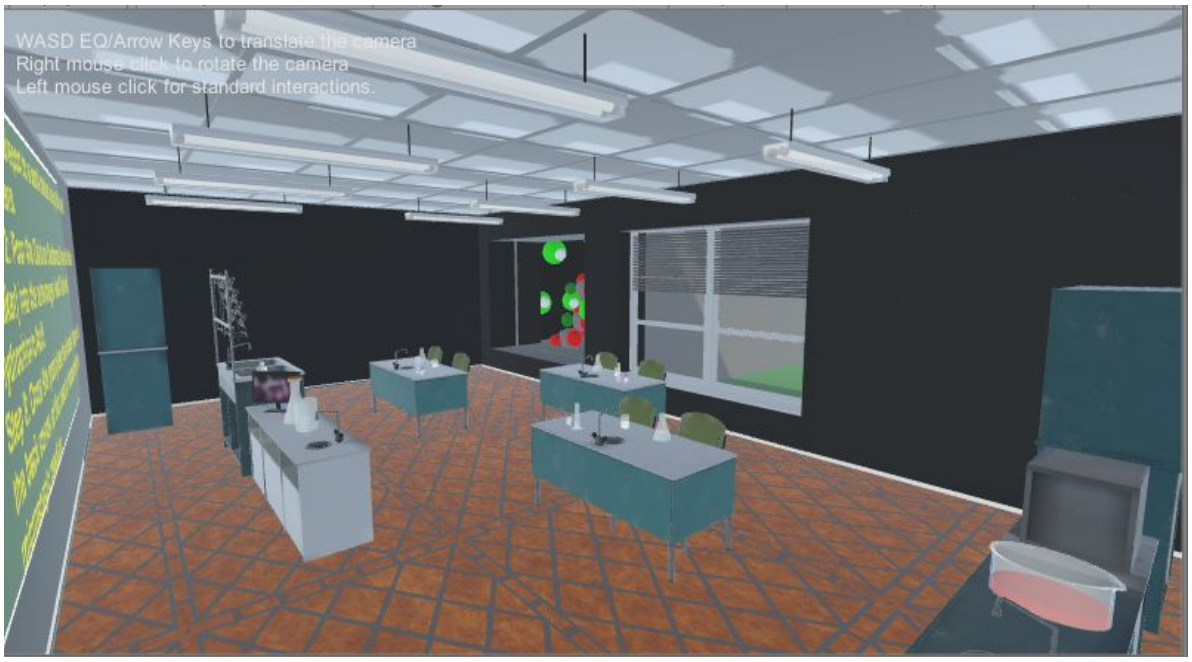

WASD EQ/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
Welcome
This game is brought to you by the VR Virtuosos
Turn around to start the pre-lab quiz


WASD EQ/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
Question 1: Which reactants will be used to perform this experiment?
A. Calcium Carbonate and Water
B. Calcium Carbonate and Hydrochloric Acid
C. Hydrochloric Acid and Water
Turn around and enter the laboratory to start the experiment

As stated in the previous section, the recent outbreak prohibited the design team from fully completing the pre-lab quiz. To provide the client with some insight on the team's plans and expectations, text boxes were placed on the wall instead,

Next, the user is prompted to leave the quiz room and enter the laboratory. With the help of teleportation points, the student is free to move around this room and interact with a variety of chemistry lab equipment. The design team's goal for this room was to make all its contents accurate and realistic. For example, the team includes a fire extinguisher, a cabinet of chemical solutions, and a water table. All these contents are found in most chemistry laboratories, supporting the product's authenticity.

Below is a picture of what the user will see when they exit the quiz room and enter the laboratory.

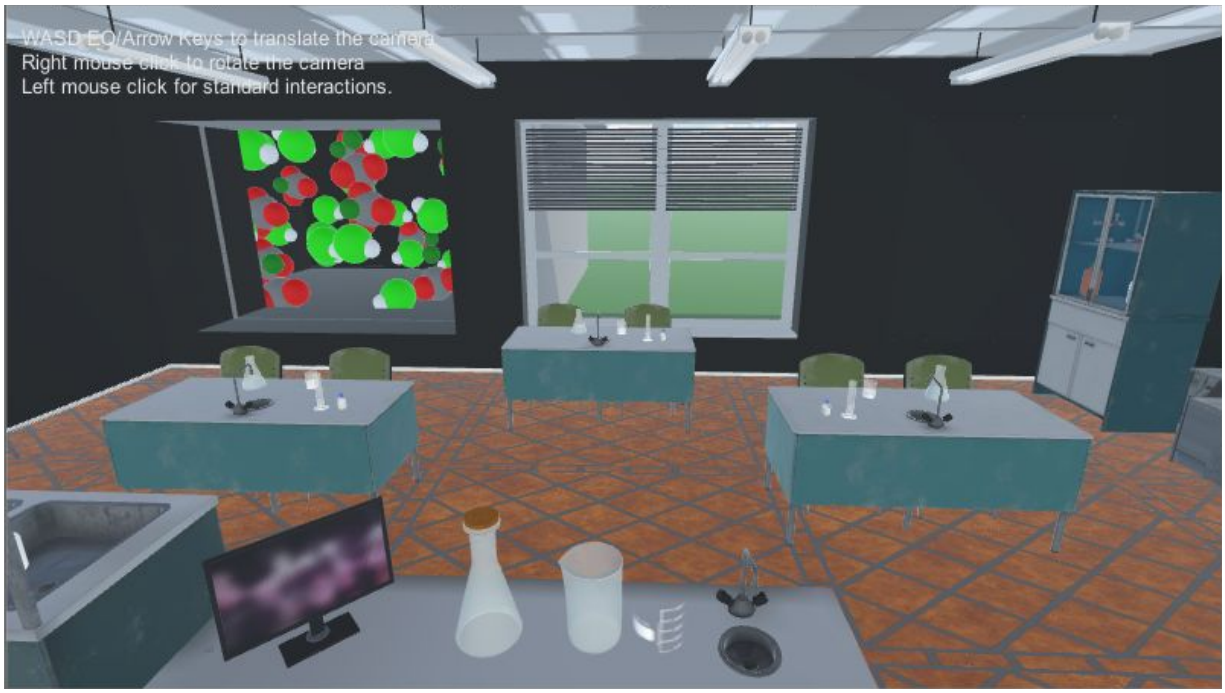


While in this room, the student will look at the blackboard for their instructions. The user is prompted to approach one of the lab benches in the VR laboratory environment. The design team included glassware and chemical solutions on each lab bench so the user can decide which station to work at. Once at this workstation, the student is prompted to begin the macroscopic reaction.

To conduct the experiment, the user must pour the $CaCO_3$ from the 50mL beaker into the Erlenmeyer Flask containing HCl. Once the student does this, they can pull the flask slightly closer and observe a precipitate forming. This white-grey aqueous solid means that the user has successfully conducted the experiment.

Although the design team was unable to test this subsystem sufficiently, it is fully completed. Ideally, the team would have tested this reaction in a variety of scenarios in the *Design Commons* to ensure that it functions properly and produces the correct outputs. As well, since this subsystem only functions with the VR hand controllers, the design team was only able to acquire pictures of the reactants, not the products.

The pictures below display the assorted glassware that the user will need to conduct the macroscopic reaction.



Once the user has successfully completed the macroscopic reaction, they will teleport to the reaction room. To enter the reaction room, the student must teleport onto a teleportation plane. The design team installed this plane to provide the users with more freedom to walk around and interact with the chemical models. Another reason this feature was added was to determine when the reaction begins.

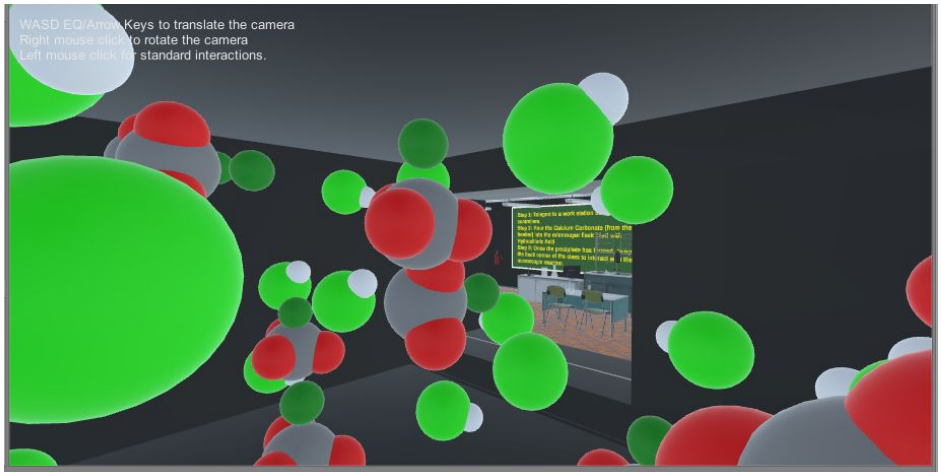
For 5.0 seconds once the student enters the reaction room, they could interact with the reactants of the $CaCO_3$ and HCl reaction. After this time, chemical bonds will begin to break, and atoms will begin moving around. At this point, the student is free to do whatever they wish; they could grab the models, throw them, or place them anywhere in the reaction room. Once this intermediate stage is finished and bonds of the products have formed, the user can interact with the products. Once again, at this point, the student can do anything they wish with the models.

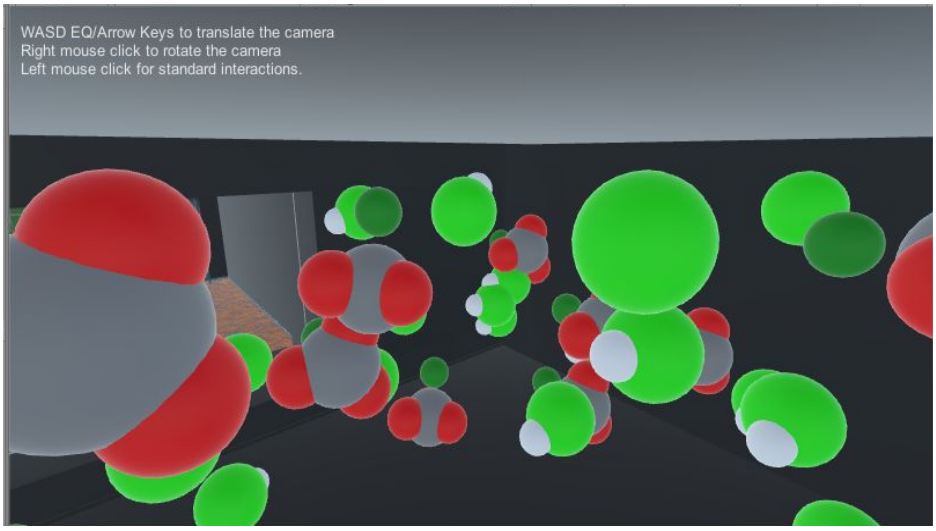
Although the microscopic reaction is simple and the molecules are not too complex, there is still a lot going on. For this reaction, the design team put in a lot of time and effort to ensure that the reaction is scientifically accurate. Some examples of misconceptions that the team addressed by creating this product include collision success, reaction speed, and relative size of molecules. By ensuring that this reaction is accurate and authentic, the design team has successfully created a superior prototype in comparison to similar products on the market.

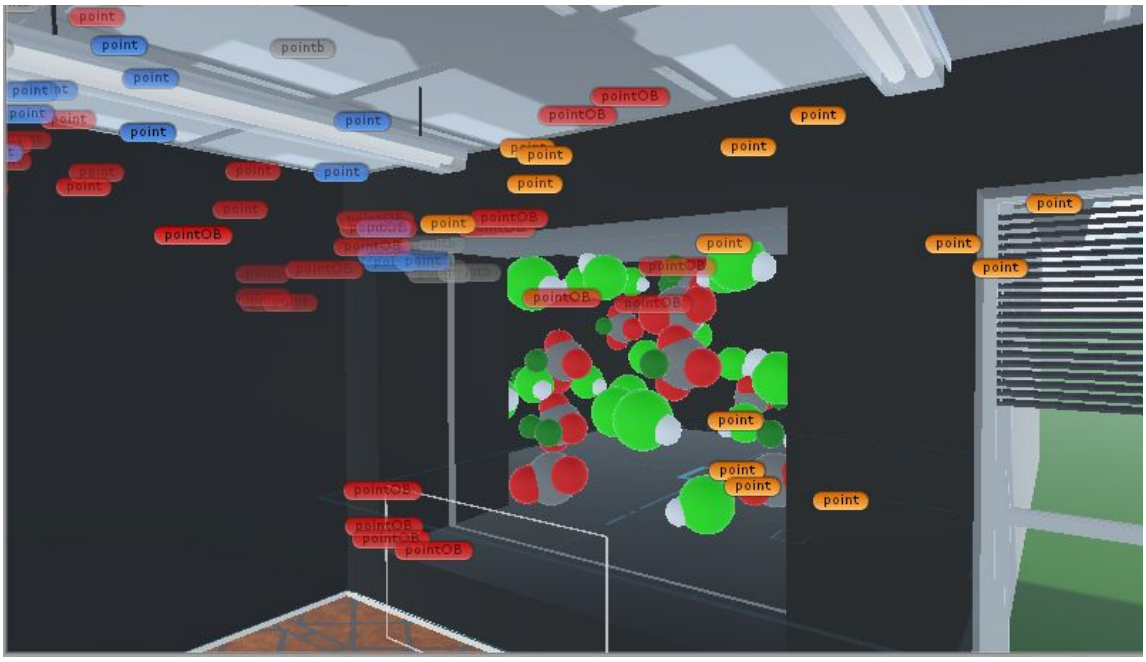
Just like the macroscopic reaction, the unexpected closure of the *Design Commons* restricted the design team from sufficiently testing this reaction. The team would have preferred testing the subsystem in more scenarios, to ensure that it functions properly and produces accurate outputs. As well, since the team did not have access to the VR hand controllers, it was not possible to test whether the teleportation area switch works properly. These uncertainties would certainly need to be considered before distributing this product to actual users.

As seen in the photos below, the design team was only able to obtain pictures of the reactants at the microscopic level. Since this subsystem only works with VR hand controllers, the team was unable to get photos of the reaction at the intermediate and product stages.

The pictures below display the reaction room and its contained molecular models at several different angles. Also included is a photo displaying the molecules' collision paths and collision points.





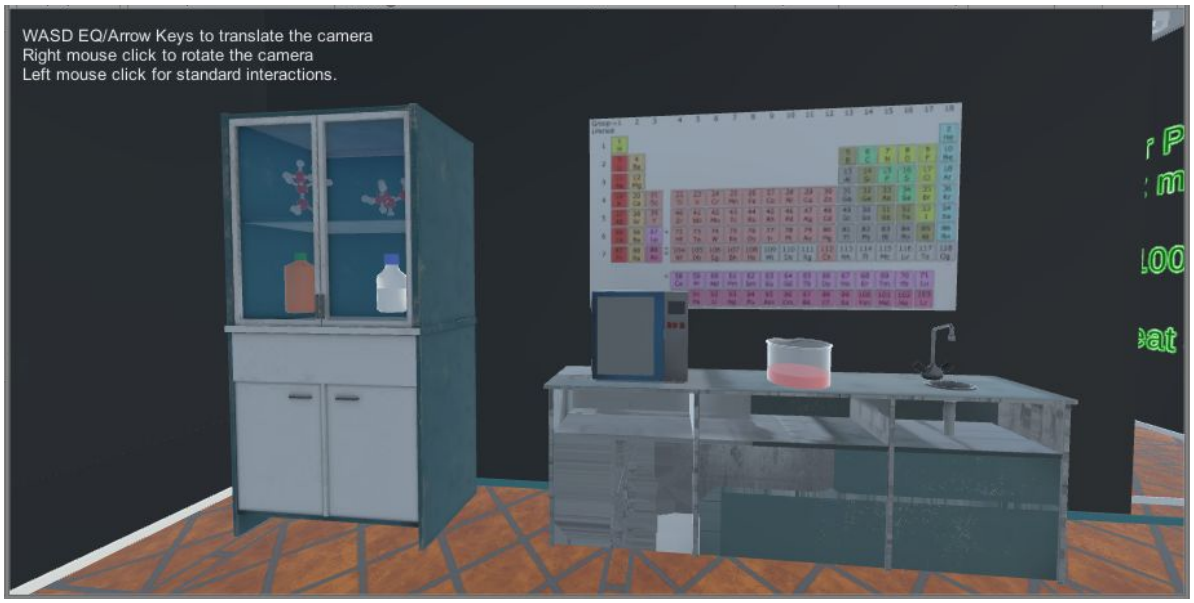


Aside from these visible components of the final prototype, the design team incorporated several other intangible techniques. Firstly, the team included a “player” into the product; this allows the user to experience a first-person viewpoint of the reactions. This technique was used to make the experience more realistic and authentic. Next, the design team added teleportation points and a teleportation area. As previously stated, these techniques allow the user to move around the environment and interact with the VR system however they please.

Below is a picture containing several teleportation points and the main player icon.

Along with these *Unity* techniques, the team incorporated grabbing scripts all over the final product. These scripts (code), when associated with an object in the environment, allow the user to physically interact with the object. With this addition, the user can obtain more knowledge on a variety of chemistry equipment, like a metallic stirrer or a glassware toaster for example. The design team took time incorporating these scripts around the environment to ensure that students have the most authentic and accurate experience possible.

Below is a picture containing various objects the user can interact with in the laboratory environment.

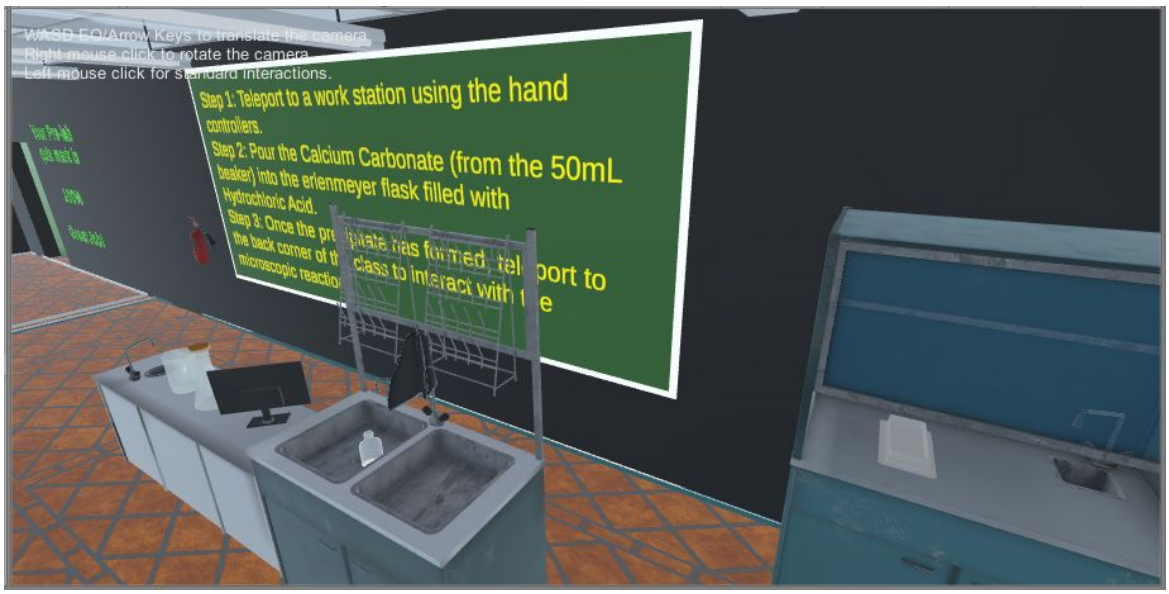


Apart from all the reactions and user interaction stations, there are still some aspects of the final product that have not been explained. The design team took a lot of time making the environment and final prototype aesthetically pleasing. Some examples of this include the choice of paint colour around the rooms and the authentic layout of the laboratory.

After the first test of the final product, the design team found that the original white-grey walls distracted the user from some of the details in the room. To truly emphasize the lab equipment and chemical reactions the team chose to make the walls and ceiling dark grey. After this change, the periodic table on the wall, the blackboard, and the sampling equipment became much more prominent.

Some examples of the accurate laboratory layout include the teacher's desk at the front of the lab and the water table near it. This layout is accurate based on the design team's prior experience in chemistry labs. As well, the design team accounted for lab safety when creating the final prototype. This was done to make the experience as realistic and authentic as possible. Some examples of this include the fire extinguisher at the front of the lab and the fire blankets in the cupboard near the teacher's desk.

Below are some pictures of the laboratory environment focusing on the chemistry equipment and general layout.



All the details provided describe the final state of the product after the design team has completed as much as possible under the unexpected circumstances.

Planned Execution under Normal Conditions

As previously stated, the recent COVID-19 outbreak caused the uOttawa CEED facilities to close. This means that there were several aspects of the final prototype that were not completed or tested. The aspects of the product that were not completed or tested properly include the following:

- Pre-Lab Quiz
- Student Help Menu
- Testing of the Macroscopic and Microscopic Reactions

Any aspects of the final product that required the VR headset and controllers were not completed or tested sufficiently.

Despite these aspects not being completed, the design team will provide a step-by-step action plan that would have been followed under normal conditions. This action plan will be in the form of a *Trello* Board and a Gantt Chart since they will effectively show task length, dependencies, and owner. The design team will also provide the testing plan that would have been followed to evaluate the product's performance compared to the target specifications developed in Prototype C.

Description of Uncompleted Aspects

As stated earlier in this deliverable, *Unity 3D* no longer supported the asset that the design team purchased for the **pre-lab quizzes**. After discovering this issue, the plan was to work on this subsystem on March 16, the same day that the CEED facilities closed. Since the team did not have access to the *Design Commons*, and it was too difficult to work on this subsystem remotely, this aspect of the final product was not completed.

The pre-lab quiz should not have taken any longer than a day to complete; the team would have taken time to find a new asset, input the already-determined questions, and then implement them into the global system. Testing would have also been conducted on this subsystem later, to ensure that it is outputting the correct information.

For the **help menu**, the original plan was to work directly in the global system, rather than in an individual file. The team planned to work together in the *Design Commons* and complete this subsystem in one day. Efforts were made to complete this aspect remotely, through *Zoom*, but it was too difficult and extremely inefficient. As well, the team kept running into issues with the *Steam* assets. Issues with script-writing and player manipulation were the biggest causes for the team not completing this aspect of the final product.

This aspect would not have taken any more than a few hours to complete in the proper circumstances. The lack of facilities and “social distancing,” however, would have forced the team to commit a few days to this subsystem, which is unreasonable and inefficient. Testing would have been conducted later, when the design team would have access to the VR headset and hand controllers.

To complete the product, extensive **testing of the macroscopic and microscopic reactions** was required. Testing was required to ensure that these subsystems were functioning properly and displaying accurate content to the user. To conduct the required tests for these subsystems, the design team needed the VR headset and hand controllers from the *Design Commons*. As well, since both subsystems require input from the hand controllers, it is not possible to test using a PC.

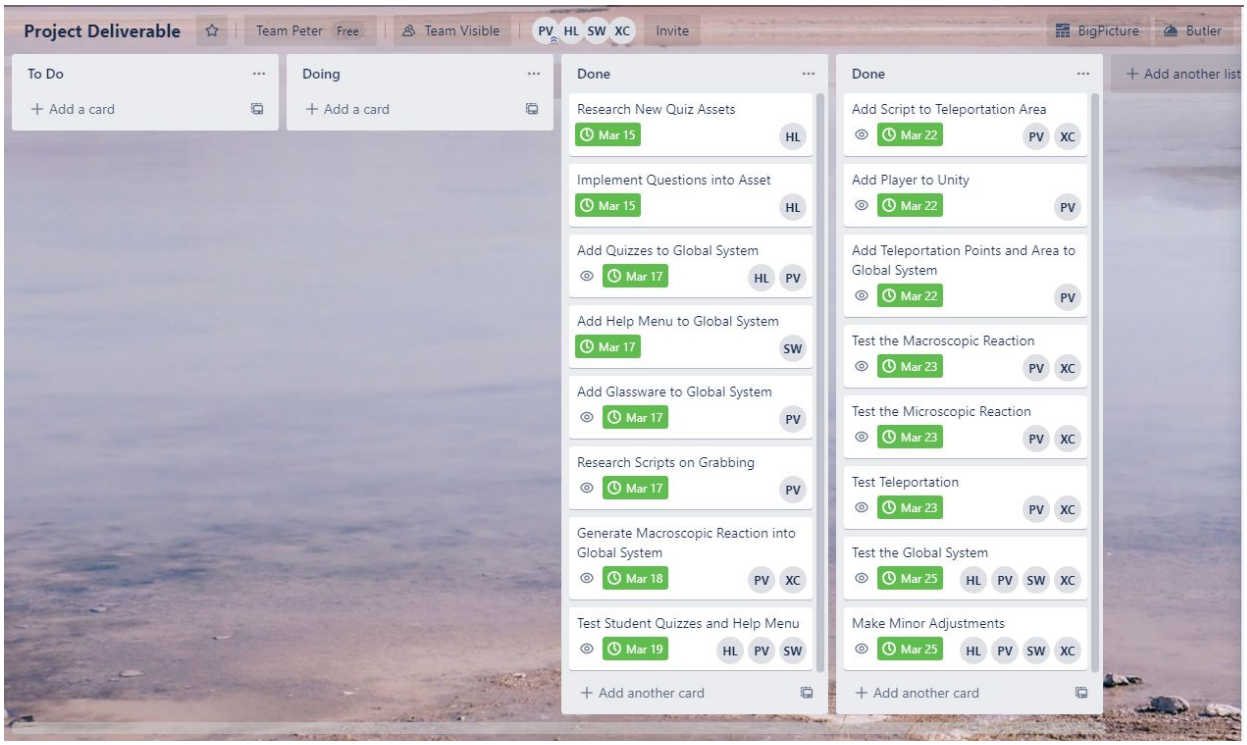
The macroscopic reaction is quite simple. There is glassware on a lab bench for the students to conduct the experiment. This subsystem requires input from the user (pouring the $CaCO_3$ into the flask of HCl) to display the products. Without the input, which comes solely from the VR hand controllers, the macroscopic reaction can not be executed. The only way for the design team to test this subsystem is to use the hand controllers from the *Design Commons*. Since this facility closed, the team was unable to sufficiently test this aspect of the final product.

A few more moving parts were added to the microscopic reaction. After testing with PC, before the CEED facilities closed, the design team discovered that the microscopic reaction started at the moment the player entered the environment. To fix this, a teleportation area, with a script attached to it, was added to the reaction room. The script enables the reaction to start only when the player enters the reaction room, rather than when they first enter the environment. This feature, however, only works when the VR hand controllers are used for teleportation. Since there was no access to the necessary testing equipment, the team was unable to sufficiently test this aspect of the final product.

Step-by-Step Action Plan

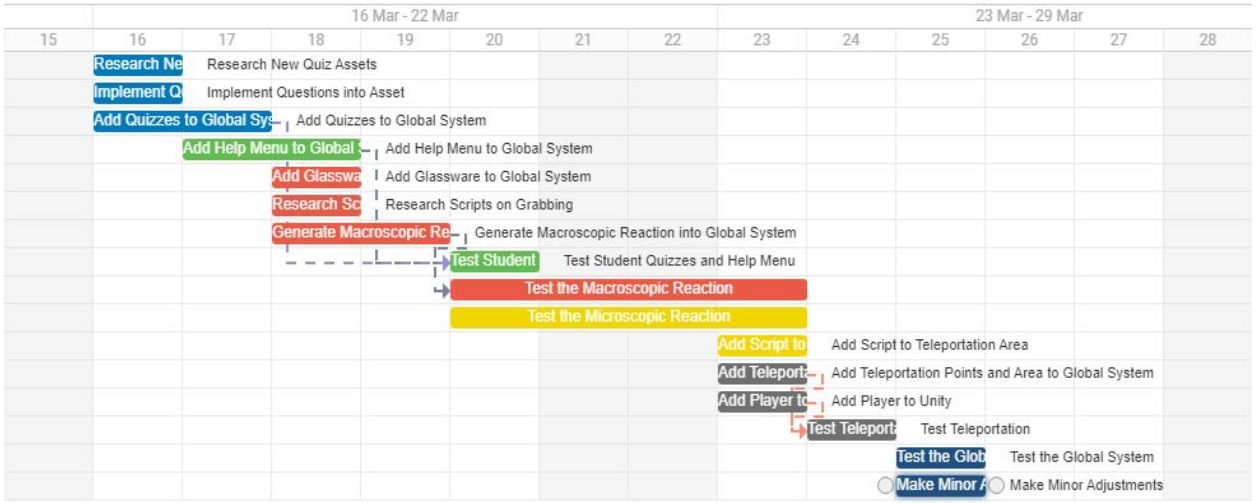
In this section, the design team will provide the plan that would have been followed to complete the project, under normal conditions. The team describes the events over 1.5 weeks, more precisely, from March 16 to March 26. The tasks that remain to be completed will be displayed in a “to do, doing, and done” board; this format will make it easier to see the individual steps. As well, a Gantt Chart will be provided. This format makes it easier to display any time constraints, interdependencies, and owner of the tasks.

Below is a ***Trello* board** containing the design team’s remaining tasks. Also included in this board are task owner(s) and due dates. Despite the considerable number of tasks in such a short span, the team is confident that all these events would have completed under different circumstances.



Some special notes that must be considered when analysing this *Trello* board involve communal testing. The *Design Commons*, where the design team conducts all VR testing, is a shared space. Since this area is on a “first come, first serve basis,” the team allotted extra time for testing in case the space was unavailable.

Also included below is a **Gantt Chart** representation of the tasks presented above. With this more visual interpretation, the design team can more easily see due dates, time constraints, and interdependencies.



Some interdependencies in the chart below are assumed, but the design team included them anyway. For example, the testing of a certain subsystem can not be completed until that subsystem has been worked on.

As well, to help distinguish tasks, the team colour-coded the Gantt Chart by subsystem:

- Blue - Student Quizzes
- Green - Help Menu
- Red - Macroscopic Reaction
- Yellow - Microscopic Reaction
- Grey - Player Creation and Teleportation
- Navy - Global Product

Another important note that the design team must provide concerns the final presentation and preparations for Design Day. Although these tasks are not included in the Gantt Chart above, since they do not directly impact prototype generation, they are still very important. The design team's original plan was to divide the tasks and work on them independently.

Despite the design team not being able to complete the final product because of the unexpected circumstances, it was still important to include the action plan. It is crucial to include this information in case other students or professionals wish to continue the project.

Evaluating Prototype Performance

The design team created a target specification table for Project Deliverable C. This table allows the team to compare the final prototype's performance to the performance of similar products on the market. With this table, the design team can evaluate the final product quantitatively and qualitatively.

Since the design team was unable to complete the final product, it is not possible to evaluate its specifications. Instead, the team will provide the systematic testing and analysis procedure that would have been followed under normal circumstances. It must also be noted that the VR system is a software, meaning it has very few measurable attributes, so a lot of qualitative testing would be done instead. Some of the qualitative attributes include, "easy of use," "physically interactive," and "immersive."

Below is a summary of the procedure that the design team would have followed to evaluate the final product's performance with respect to the target specifications developed in Project Deliverable B:

1. Create a log to track feedback from different trials
2. Using the VR headset and controllers, the design team runs through the final product
3. Collect feedback from the design team members to evaluate the product's performance with respect to the target specifications
4. Collect feedback from other design team members for further analysis
5. Using the feedback, rank the prototype's performance to those of comparable products
6. Calculate the product's overall performance and compare it to those of the other products
7. If the prototype's overall performance value is greater than those of similar products, the design team has successfully created a superior product.
8. If the value is not greater, distinguish which aspects need to be improved and make the necessary adjustments

Conducting this qualitative testing is quite simple, each member of the design team would use the final prototype and provide their feedback with respect to the attributes found in the target specifications table. To ensure an abundance of data, the team would ask another design team to try out the final product and evaluate its performance for the criteria in the table.

The design team would also keep a log to collect all the feedback and conduct further analysis. Once all the feedback is collected, the team would rank the product's performance with respect to the other products in the target specifications table. For deliverable C, the products were ranked 1, 2, or 3, with 3 being the best product for a certain specification. The design team would use this same method to evaluate the final prototype's performance for this deliverable.

Once these values are collected, the product's overall performance value is calculated and compared to those of the other products. If the calculated value is greater than those of all the similar products, then the design team has successfully created a superior product.

Potential Client and User Feedback

By consulting user feedback and advice from potential clients, the design team can enhance and improve the prototype drastically. By receiving feedback and advice on the prototype, the design team can determine what works, what does not work, and what should be improved. With careful consideration of the advice given by others, the design team can have a new perspective on the VR system and how it can be better.

Although the final product was incomplete, screenshots of the unfinished prototype were shown to a first-year organic chemistry student for feedback. Despite the student not being able to see the finished product, the design team still acquired crucial feedback.

The student stated that they really liked the environment and the layout of tasks (quizzes, help menu, reaction, etc.). As well, they stated that more teleportation points should be included for the user. This would provide the user with more freedom to move around the environment, which was also a significant need of the client. The student also said that they enjoyed watching the chemical reaction (from another file). They stated that it was pretty accurate, however, more molecules taking part in the reaction would be even better.

Overall, the student said that they like the final stage of the product and would be interested in using the product if it were completed.

With the feedback from the student, the design team is satisfied with the product at this final stage. Although all members of the team would have preferred creating a finished product, this positive feedback is reassuring. Now knowing some areas that could potentially be improved, it would be easier for the design team to generate a better product if it were ever completed in the future.