

## Prototype II and Customer Feedback

For this deliverable, the design team has created a second prototype for the VR system. The goal of the prototype is to confirm that the primary prototype was functional and that future ideas are attainable. It is important to note that this is the final prototype before Design Day; therefore, the design team will begin adding certain cosmetics and other features not included in the first prototype. It can also be said that this is the most crucial prototype, as this is the stage where it will be known whether the design works. Explicit details will be provided, along with many pictures, to document these prototypes; this will allow the team to innovate past ideas, improve the global product, and save crucial time in later stages of production.

Along with generating the prototype, many tests will be conducted on the product. This will help the design team analyse the prototype and distinguish which components are functional. The testing of the prototype will follow a specific procedure, ensuring that all prototyping goals have been achieved successfully. Different testing methods will be used on the various components of the product. The purpose of the unique testing is to confirm that every subsystem works well independently before they are added to the global system.

Unlike the first prototype, an analytical, numerical, or experimental model will be included for this deliverable. This will allow the design team to further analyse the prototype and ensure that it is functioning properly. Each modeling method is required in unique circumstances and requires unique procedures. The design team will be documenting these models thoroughly for further research and analysis.

Lastly, feedback and comments on the prototype will be gathered from potential clients and users. The design team will use this feedback to improve the product and potentially research different methods for creating the VR system.

### Comments on Prototype I

It was clear after completing the first prototype that the design team was making substantial progress and getting even better test results. For the primary prototype, only subsystems were generated, rather than a global prototype. The second prototype will include several subsystem prototypes and a few global solutions, where several subsystems are joined.

In the previous prototyping stage, molecular models, Unity techniques, chemical reactions, the help menu, and student quizzes were developed. The goal of this prototype is to enhance some of these subsystems and improve their performance, along with joining some of them together. For example, the help menu will be implemented into Unity, which joins two subsystems from the previous prototype.

Another crucial note from the first prototype came from the client. The client stated that they prefer having only one detailed reaction for this product, rather than 2 general representations. With this feedback in mind, the design team decided to remove the second reaction from the product. Therefore, the methane to methanol reaction will not be used, which saves a lot of time and effort for the design team.

Once the first prototype was completed, the design team learned that time management and prototyping fidelity are crucial. These factors will be critical in helping the design team continue making progress and produce functioning prototypes.

## Prototyping Phase

A prototype is a representation of a part or an entire design concept. The purpose of prototyping is to learn more about a design concept and to understand it more clearly. Along with obtaining more knowledge on the design, the performance of the system and subsystems can be observed. These are the key aspects of a prototype, all of which are used to innovate and improve the product.

The design team decided that the prototypes for this deliverable will be both physical and analytical. Physical means that a 3D subsystem will be generated, and its performance can be measured before it is included in the general system. Analytical means that more math and science will be generated and analysed for the subsystems; these analytics will then be implemented in later prototypes. For this deliverable, both focused and comprehensive prototypes will be generated. Focused means that only the subsystems of the product will be prototyped; comprehensive, however, is when two or more subsystems are joined to create a larger system.

It must be noted that most of the subsystems of this product cannot be physically created; the design team has worked to create realistic virtual concepts. The following subsystems will be prototyped for this deliverable:

- Molecular Movement and Collisions
- Virtual Reality Environment
- Implementation of the Help Menu
- Further Research into Student Quizzes and Progress

Each of these subsystems or product components are being prototyped for several reasons. Some of these reasons include getting user feedback, verifying feasibility and time constraints, analysing critical subsystems, and reducing risk and uncertainty. These reasons help distinguish the importance of the various prototypes, which is quite helpful for the design team when managing its time.

When deciding on which prototypes to generate, several questions must also be asked and answered by the design team. The design team will clearly identify the purpose of creating the prototype, what type of prototype is being created, and how it will be generated. This is done to ensure that the design team is aware of the objectives of the prototype and that all critical components of the product are addressed.

Some other important questions that must be addressed include the amount of time and materials needed to make the prototype and the cost to produce the prototype. Once all these questions have been answered and the prototypes have been created, the testing phase can begin.

## Prototyping Molecule Movement and Collisions

To prototype the molecular movement that will be executed during the reactions, a significant amount of shape construction and vector displacement must be used. Using skills acquired in the lab and with online Unity tutorials, the molecular movement could be accomplished. To begin with, no physical prototypes were created for this subsystem; they were only generated using software. This is beneficial to the design team because the movement and collisions of the models are generated using Unity software and will be implemented into the global system using Unity software. Instead of using time and effort to create physical models to execute collisions, this subsystem prototype will only be computer-generated.

As seen below, several questions are to be asked when prototyping the subsystems, to ensure that the design team is aware of the component's objectives.

<b>Prototyping Questions</b>	<b>Response</b>	<b>Brief Explanation</b>
Purpose of the prototype?	To analyse critical subsystems, to reduce risk and uncertainty, and to maximize scientific accuracy	By going in-depth into the details of the molecules' movement and collisions, the design team can make these reactions as accurate as possible, which was a significant need of the client.

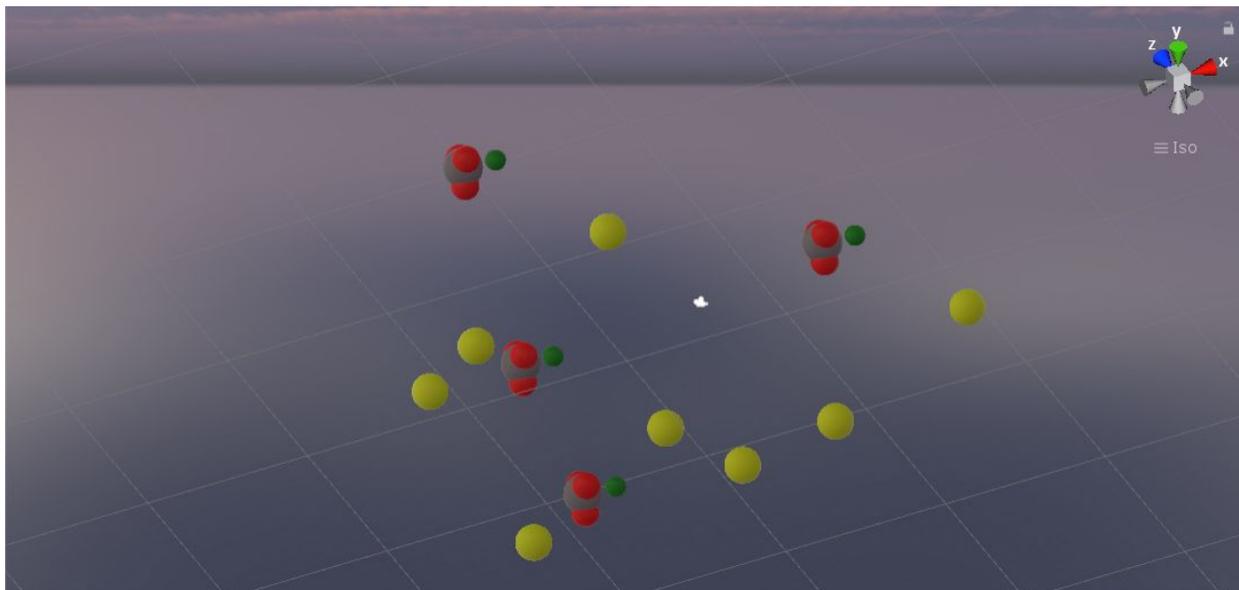
Type of prototype?	“Physically” focused	Only one subsystem was generated for this prototype: focused. Although a physical structure will not be made, the molecular movement still represents those of actual chemical reactions.
How will it be generated?	By consulting several Unity 3D motion tutorials and lessons from the lab	Several Unity tutorials for 3D motion were consulted when generating the motion of the molecules. Lessons learnt in the lab were also used when prototyping the movement of the models. By taking advantage of these resources, the design team was able to create the most accurate chemical reaction possible.
Materials needed?	Unity software	The Unity software was used to generate the movement of the structures and was the only “material” needed.
Cost to produce?	None	There was no cost needed to produce this subsystem prototype.
Time constraints?	6 hours	6 hours were needed to build the models. This movement could not have been generated until the chemical structures were completely finalized.

To prototype this crucial subsystem, significant attention to detail was required, ensuring that the reaction is accurate. Unity generated vector movement was used to generate this prototype as it is free, and easy to use. Since this software was used to create this subsystem, there was no need to purchase any assets, which is helpful for the design team’s budget.

With the help of many online tutorials and the Unity help guide, this prototype was generated. Only 8 HCl molecules and 4 CaCO<sub>3</sub> molecules were used for the second prototype. This was done to ensure a firm grasp on the concept, before including too many molecules. This was also done to save the design team some crucial time, as the team only had one week to generate this entire prototype.

Below is a screenshot of the chemical reactants before the reaction takes place. The photo of this stage of the reaction is used by the design team to determine the paths that the models will be following throughout the chemical reaction. To test this

prototype, it will be determined whether the movement of the molecules coincides with the temporary paths outlined by the design team.



The prototype testing phase for this subsystem indicated that more work needs to be done to make the reaction more accurate. As well, more molecules must be included for the next prototype, to ensure that this translation method is effective and realistic. At this point, however, most of the research and basic analysis has been completed for this subsystem.

## Prototyping Virtual Reality Environment

To prototype the environment for this product, the place that will house the reactions and the help menu, a lot of shape construction and asset manipulation was used. Using skills acquired in the lab and with online Unity tutorials, the virtual reality environment was prototyped. To begin with, no physical prototypes were created for this subsystem; they were only generated using Unity. As this model will be used throughout the prototyping process as a software, it did not make sense for the design team to generate a physical prototype. Instead, a “physical” simulation of a chemistry laboratory was generated using Unity and will soon be implemented into the global system. Instead of using time and effort to create physical models to plan the environment, this subsystem prototype was only computer-generated.

As seen below, several questions are to be asked when prototyping the subsystems, to ensure that the design team is aware of the component's objectives.

<b>Prototyping Questions</b>	<b>Response</b>	<b>Brief Explanation</b>
Purpose of the prototype?	To analyse critical subsystems, and to reduce risk and uncertainty	By paying close attention to the details of the VR environment and the user's interaction with the system, the design team can effectively account for user experience. This was another significant need of the client.
Type of prototype?	"Physically" focused	Only one subsystem was generated for this prototype: focused. Although a physical structure will not be made, the VR environment still represents a physical chemistry lab.
How will it be generated?	By consulting several Unity 3D environment tutorials and lessons from the lab	Several Unity tutorials for 3D environments were consulted when generating the chemistry lab. Lessons learnt in the lab were also used when creating the environment prototype. By taking advantage of these resources, the design team was able to create the most realistic chemistry lab possible.
Materials needed?	Unity software and several assets	The Unity software was used to generate the movement of the structures and was the only "material" needed.
Cost to produce?	\$34.99	This cost was needed to purchase assets from the Unity Asset Store. These assets were used to create the chemistry lab and the lab instruments.
Time constraints?	2 days	Two days were needed to build the lab environment. There were no constraints to generate this prototype.

To prototype the environment for this product, several assets from the Unity Asset Store were required. Firstly, an asset to build the actual laboratory was needed, so “Chemistry Class - School” was purchased for \$29.99. This asset included lab benches, basic chemistry glassware, teaching supplies, classroom furniture, and various materials and textures. With these “prefabs,” the design team was able to generate the VR environment, as seen in the screenshots below.

As well, another asset was purchased, with the intent of getting more detailed glassware and chemistry essentials. To satisfy this need, the “Chemistry Bundle” asset was purchased for \$5. This asset included detailed glassware, simple chemical models, and specific chemistry equipment, like a hot plate.

With the help of these assets and a quick tutorial on 3D Unity environments, the design team was able to generate the subsystem prototype for the VR environment. Below are the screenshots of the prototype.





The prototype testing phase for this subsystem indicated that more work needs to be done to make the environment more accurate. At this point, however, most of the work has been completed for this subsystem.

### Prototyping the Implementation of the Help Menu

To prototype the help menu that will be available for users, simple coding and data displaying techniques will be used. Using skills already known by the design team from past courses, the help menu can be used to effectively help students. Once again, for this prototype, no physical subsystems were generated, only programs were produced. Since codes have no physical form, only the input and output can be observed and analysed. For this prototype, the program will be fully functional to eventually be implemented into the global system.

As seen below, several questions are to be asked when prototyping the subsystems, to ensure that the design team is aware of the component's objectives.

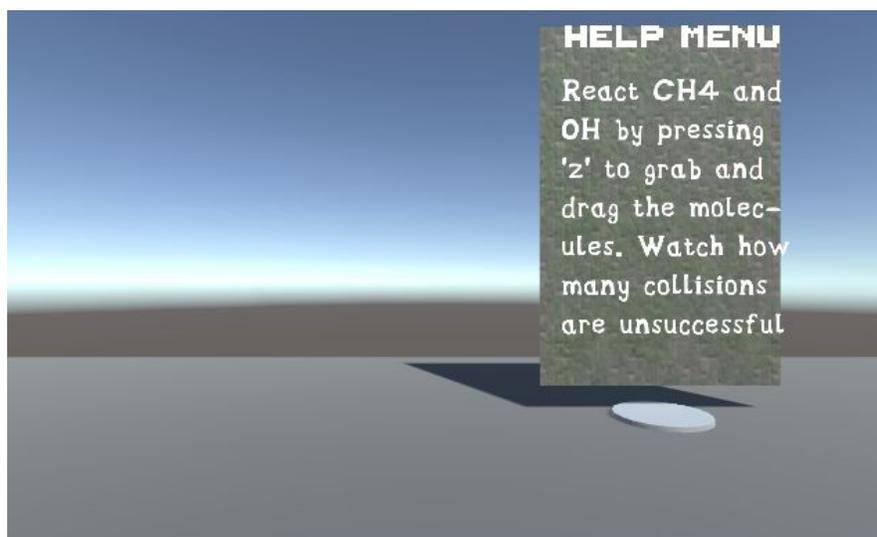
<b>Prototyping Questions</b>	<b>Response</b>	<b>Brief Explanation</b>
Purpose of the prototype?	Getting user feedback and analysing critical subsystems	By creating this program to help users, the product will be easier to use. This will help make the VR system more effective, which was a significant need of the client.
Type of prototype?	Analytically focused	Only a subsystem will be generated, and it will be analysed without a physical form. This was done to make it easier to study the input and output of the program and implement it later.

How will it be generated?	Using previously known information	Using knowledge acquired in past courses, the design team was able to implement a help menu for students. This was done to ensure that the product is effective and easy-to-use.
Materials needed?	None	Since this is an analytically focused prototype, no materials are needed.
Cost to produce?	None	Since this is an analytically focused prototype, there are no production costs.
Time constraints?	2 hours	Two hours were needed to create the program and run the required tests.

To create a successful prototype for this subsystem, most of the focus had to be placed upon the usability of the feature, and its ability to integrate into a working 3-D environment. To achieve this goal, much of the focus was placed upon creating a help menu in a simple prototype environment.

To create this prototype environment, a floor was added first. Then, a teleport target was created to simulate the target teleport location. This target is shown in the below screenshot as a white cylinder. By adding a teleport script to this cylinder, it could be deemed a landing spot. In this regard, the user can stand on the created floor and teleport to the help menu by pressing a button.

Next, a player controller, with a body, was added to test how the user interacted with the software in-game. The camera was attached to this controller, allowing the player to look around the environment.



The text was also programmed to scroll inside the window. This would allow the player to view particularly lengthy hints and advice on the menu and scroll gradually as they read.

The prototype testing phase for this subsystem indicated that more work needs to be done to make the environment more accessible and easier to use. At this point, however, most of the work has been completed for this subsystem.

## Prototyping Further Research into Student Quizzes and Progress

To prototype the implementation of quizzes and student progress into Unity, simple coding and data displaying techniques will be used. Using skills already known by the design team from past courses, these features can be used to effectively track students' merits. Once again, for this prototype, no physical subsystems were generated, only programs were produced. Since codes do not have a physical form, only the input and output can be observed and analysed. This program will soon be implemented once the global system has been generated.

As seen below, several questions are to be asked when prototyping the subsystems, to ensure that the design team is aware of the component's objectives.

<b>Prototyping Questions</b>	<b>Response</b>	<b>Brief Explanation</b>
Purpose of the prototype?	Getting user feedback and analysing critical subsystems	By creating this program to track student progress, the product will be more interactive. This will help track how effectively students are learning, which is a significant need of the client.
Type of prototype?	Analytically focused	Only a subsystem will be generated, and it will be analysed without a physical form. This was done to make it easier to study the input and output of the program and implement it later.
How will it be generated?	Using previously known information	Using knowledge acquired in past courses, the design team was able to create a menu to track student progress. This was done to ensure that the product effectively educates students.
Materials needed?	None	Since this is an analytically focused prototype, no materials are needed.

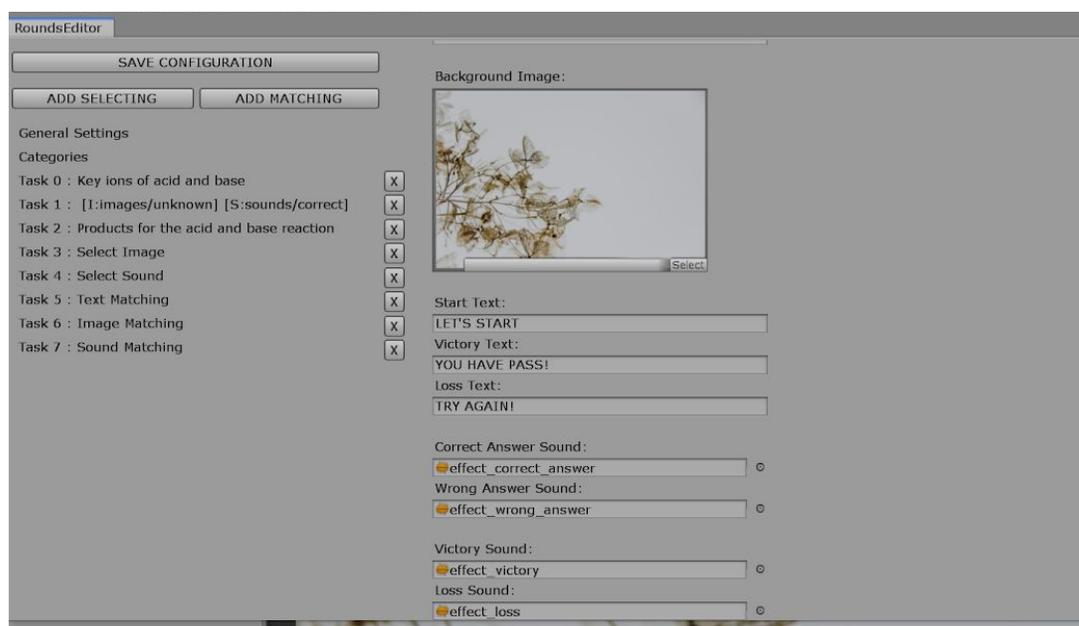
Cost to produce?	\$9.00	Since an asset was needed to generate this prototype, a cost is associated with this subsystem. This asset was used to create a basic layout and template.
Time constraints?	2 days	2 days were needed to create the program and run the required tests.

To prototype the quizzes that assess the users' knowledge and learning, a Unity asset called "Quiz Template" was used to get the basic materials and scripts for the process. This cost to produce this subsystem prototype was \$9.00.

There will be two quizzes for this product, one before the reaction and the other one after the reaction has been completed. The "pre-lab quiz" will be used to test whether the student is prepared for the reactions. This is done by asking questions on the background information of the reaction. The questions will be multiple choice; this was done because it is easy to use and efficient.

The "post-lab quiz" will be taken by the users once the reactions have been completed. These questions are slightly more difficult, as they include topics that were covered during the reaction. This quiz will include both multiple choice and matching questions; this was done to make the quizzes more interesting and interactive.

Below are screenshots of the asset that was purchased. The menus include below allowed the design team to customize the quizzes and make them interesting for users



RoundsEditor

SAVE CONFIGURATION

ADD SELECTING    ADD MATCHING

General Settings

Categories

Task 0 : Key ions of acid and base

Task 1 : [I:images/unknown] [S:sounds/correct]

Task 2 : Products for the acid and base reaction

Task 3 : Select Image

Task 4 : Select Sound

Task 5 : Text Matching

Task 6 : Image Matching

Task 7 : Sound Matching

CATEGORIES:

Text: Pre-lab quiz   X

Text: End lab quiz   X

ADD CATEGORY

TASK:

Text: Key ions of acid and base

Sound:  None (Audio Clip)   Select

OPTIONS:

Text: H2 AND OH-

Sound:  None (Audio Clip)   Select

Text: CH AND O-

Sound:  None (Audio Clip)   Select

Text: H2 AND O-

Sound:  None (Audio Clip)   Select

ADD OPTION

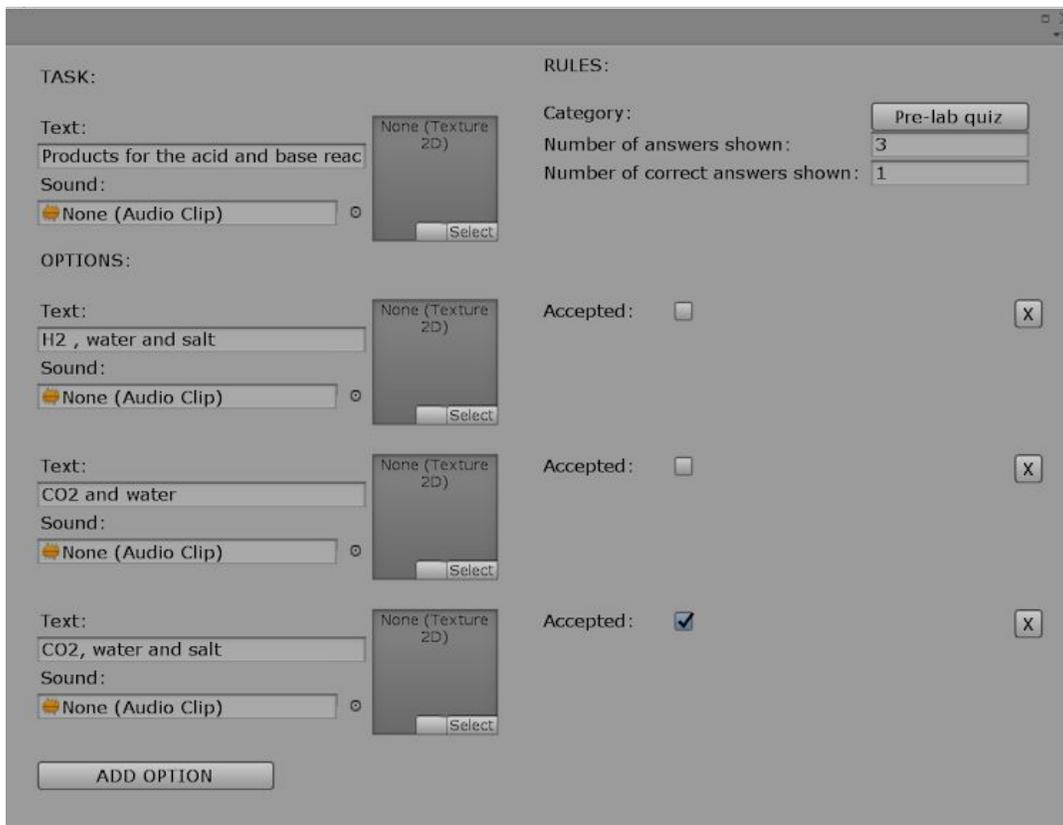
RULES:

Category:  Pre-lab quiz

Number of answers shown:  3

Number of correct answers shown:  1

Accepted:       X



If the students answer questions incorrectly, the console will shine red and the student will be prompted to try again. The client will decide how many chances the user gets to answer correctly. For this prototype, the student has three chances to get the right answer, if all the chances are used, the student will be prompted to restart from the beginning.

The prototype testing phase for this subsystem indicated that more work needs to be done to implement this prototype into the global system. At this point, however, most of the work has been completed for this subsystem.

## Testing Phase

Testing is a crucial aspect of engineering design. It allows designers to know when their product has successfully met its requirements or whether more can be done to improve the product's performance. Testing also ensures that all components are functioning properly and that there are no identifiable design flaws.

Some more benefits of testing include forecasting demand, observing various materials, product benchmarking (comparing performance with other products), and verifying if the product is ready to launch. To properly test a product's performance and analyse its features, the design team must create a test plan.

A good test plan includes the following steps:

- Define the purpose of the test
  - What is the design team trying to analyse from the prototype?
- Choose a subsystem
  - Choose measurable attributes
- Choose a testing method
  - Simulations, physical concepts, etc.
- Perform the test
- Measure and record the results
  - Can the design team's analysis be used to improve the product?
- Interpret the results
  - What can be improved?

All these steps will be covered when testing this prototype. As stated earlier, not all subsystems will require the same tests; the procedure above is a general test plan. It is important to note as well that physical models will not be possible for several subsystems, so testing methods will be more opinion-based than analytical.

The three main questions that must also be answered for each prototype are **why**, **what**, and **when**. As previously stated, each prototype has a purpose and a goal; this is the **why**. **What** is the type of prototype and what information is being collected and analysed. Lastly, **when** is the time constraints and the interdependencies of the individual prototypes. To ensure that unnecessary confusion does not arise, all these questions should be answered before and after each prototype is tested.

## Testing Molecular Movement and Collisions

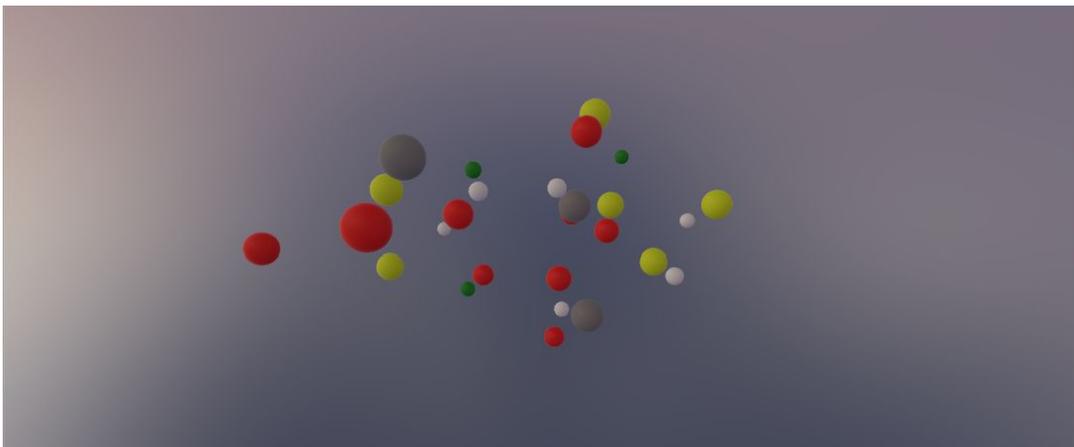
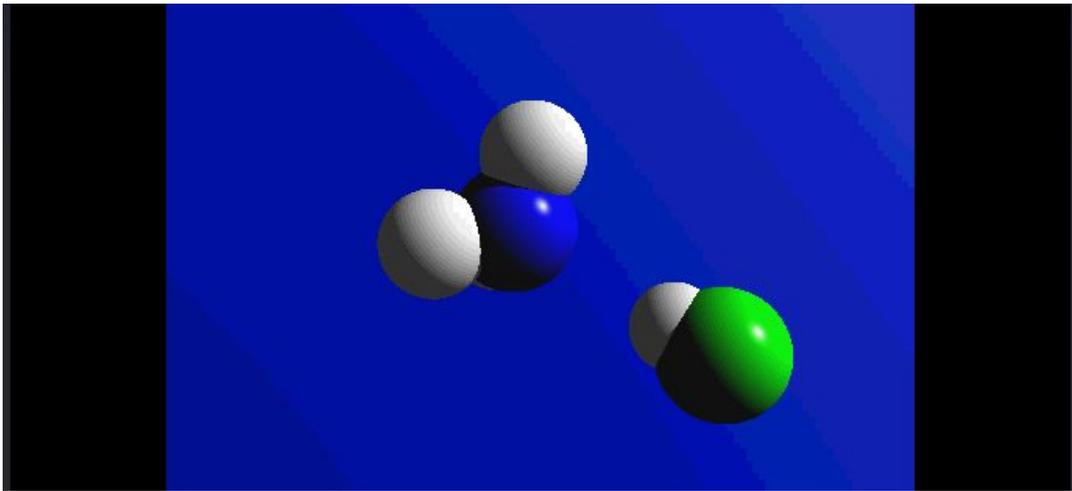
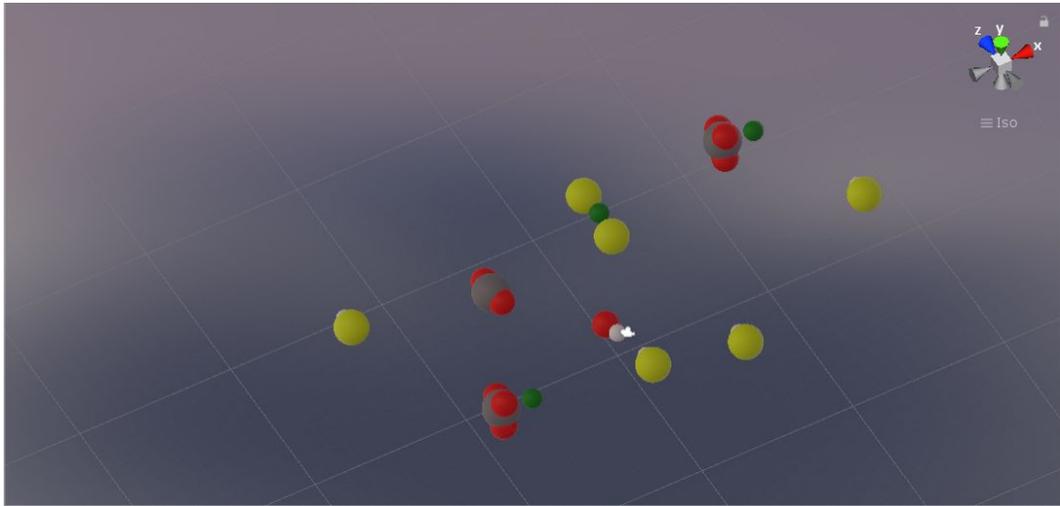
Testing "physically" focused software-developed prototypes is different from conventional physical prototypes. There are very few measurable performance quantities that can be measured, which makes the testing judgment, and trial and error oriented.

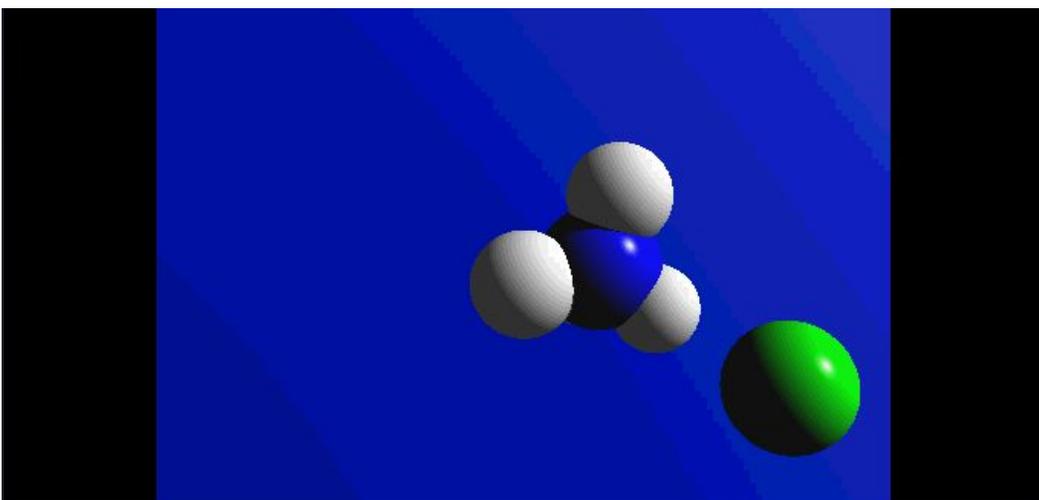
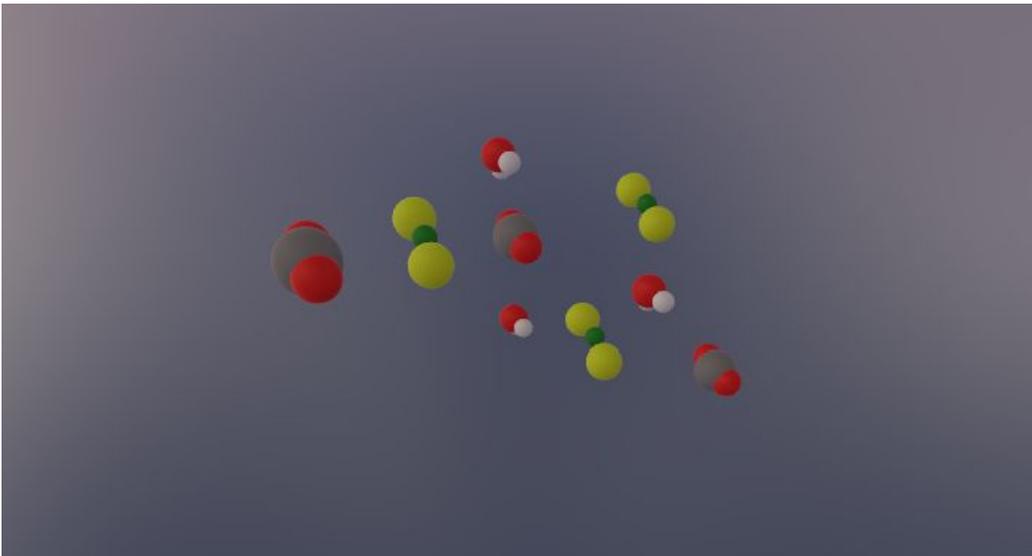
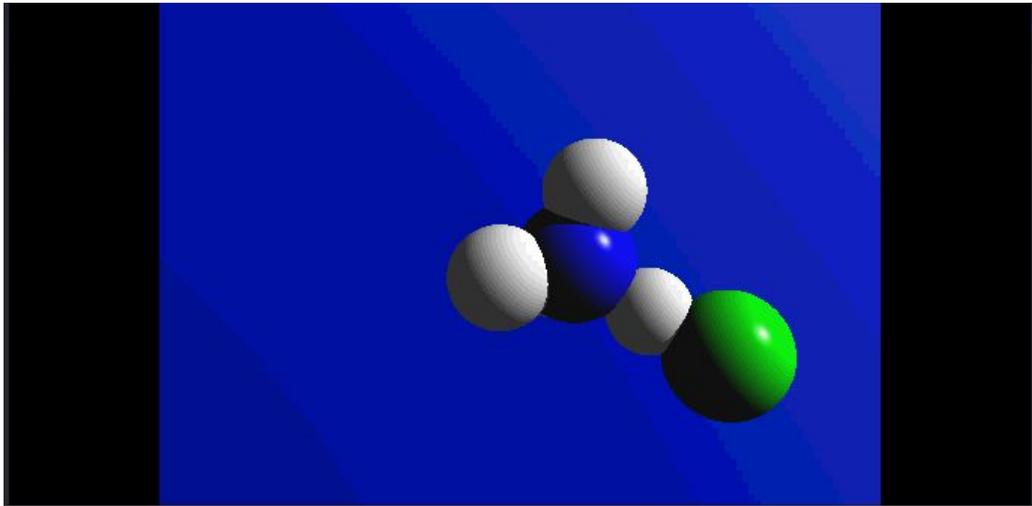
Below are the questions that must be asked before and after testing the movement of the molecular models; this is to ensure that the testing is beneficial, and that substantial progress is being made.

<b>Why?</b>	The purpose of this testing is to confirm that the collisions between the chemical structures are accurate and can be implemented effectively into the chemical reactions. As stated earlier, further analysis and scientific accuracy are the main goals of this prototype. The results of this testing will determine whether the team needs to use another method to move the molecular models or conduct further research. For this test to be considered a failure, the models' movements would not coincide with those from other resources (found on the internet using simulations).
<b>What?</b>	The prototype type that is being tested is "physically focused." As stated, there are very few measurable attributes for this subsystem prototype. To test this prototype, the chemical motions and collisions will be compared with those of several online resources. Due to the prototype being software developed, no costs need to be allocated for the testing. The only "material" needed is Unity, with which this subsystem is generated.
<b>When?</b>	This prototype only had one dependency. Without the chemical structures being complete and accurate, this subsystem prototype could not have been created. Once the chemical models were completed, this prototype generation and testing could begin. All the testing for this reaction took roughly 30 minutes. During this time, several videos and tutorials were analyzed for an in-depth comparison with the prototype.

Since there are very few measurable attributes for software-generated prototypes, no formal testing could be conducted for this prototype. Instead, informal observation was used to ensure that the molecular movements and collisions were successful and accurate. To "test" this prototype, the design team looked to confirm that the models were behaving as expected. To do this, the Unity generated prototype was compared with an online resource, like Odyssey or VisiChem.

Below are screenshots of the chemical reaction at various stages. The stages of the Unity generated reaction that will be compared with those from online resources. For the first picture, only the reactants are included ( $\text{HCl}$  and  $\text{CaCO}_3$ ) and they are compared with those from an online deprotonation reaction. For the next picture, the reactants are in the process of breaking bonds and forming new ones, like the ones from VisiChem. In the final picture below, the products ( $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{CaCl}_2$ ) can be seen, just like the molecules from the internet.





After the design team compared the two chemical reactions, it was clear that the design team is making substantial progress. The design team must now create the reaction on a larger scale, to accurately display the reaction at the microscopic level.

## Testing Virtual Reality Environment

Testing “physically” focused software-developed prototypes is different from conventional physical prototypes. There are very few performance quantities that can be measured, which makes the testing judgment, and trial and error oriented. Especially in this case where there are no measurable attributes, the design team must develop a unique test plan.

Below are the questions that must be asked before and after testing the movement of the molecular models; this is to ensure that the testing is beneficial, and that substantial progress is being made.

<b>Why?</b>	The purpose of this testing is to confirm that the virtual reality environment looks realistic and organized. It will also be confirmed that all the necessary assets have been implemented properly. As stated earlier, further analysis and user feedback are the main goals of this prototype. The results of this testing will determine whether the team needs to further develop the chemistry lab environment or consult others for help. For this test to be considered a failure, the VR environment would not be an accurate simulation of a chemistry lab, and it would be poorly organized and awkwardly arranged.
<b>What?</b>	The prototype type that is being tested is “physically focused.” As stated, there are no measurable attributes for this subsystem prototype. To test this prototype, the chemistry lab will be compared with those from the design team’s experience and of several online resources. Due to the prototype being software developed, no costs needed to be allocated for testing. The only “material” needed for testing is Unity, with which this subsystem is generated.
<b>When?</b>	There are no dependencies to perform this test, as this is only a subsystem prototype. The focus remains on making the product accurate and organized, to maximize user experience. All the testing for this reaction took roughly 30 minutes. During this time, the Unity generated chemistry laboratory was compared with those from previous experiences and various online resources.

Once again, since there are very few measurable attributes for software-generated prototypes, no formal testing was conducted for this prototype. Instead, it was ensured that all important aspects of the environment were organized and accurate. To help with this process, the VR environment was compared with other chemistry labs, either from personal experience or online resources.

Below is the picture that inspired the general layout of the design team's environment. As well included below are more screenshots of the Unity generated surroundings for this prototype. These pictures were compared to ensure that all the crucial components of a chemistry lab were included and look realistic.





Since the real chemistry lab and the environment generated using Unity are similar, the prototype is considered a success. The lab benches, mini sinks, and general equipment are organized in similar manners; this indicates that the software-built environment is accurate.

Next, the design team must combine the subsystem prototypes together and generate a global system with this VR environment.

### Testing the Implementation of the Help Menu

Testing analytically focused prototypes is different from conventional physical prototypes. However, in this case, since a program has been created, it is possible to test the inputs and outputs of the program.

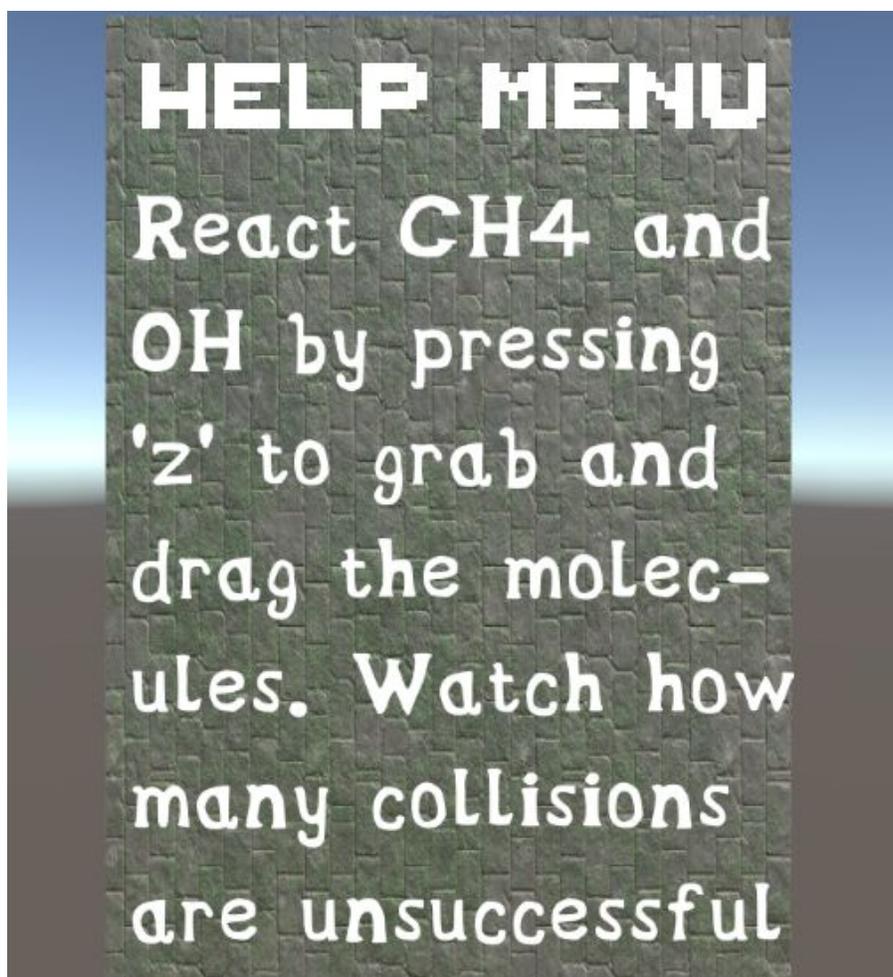
Below are the questions that must be asked before and after testing the help menu; this is to ensure that the testing is beneficial, and that substantial progress is being made.

<b>Why?</b>	The purpose of this testing is to confirm that the help menu effectively outputs the necessary information to users. As stated earlier, user experience and customer feedback are the main goals of this prototype. The results of this testing will determine whether the team needs to recode the program or to reconvene with the client. For this test to be considered a failure, the program will not output the correct information to the user.
<b>What?</b>	The prototype type that is being tested is “analytically focused.” As stated, there are very few measurable attributes for this subsystem prototype. To test this prototype, various inputs will be provided for the code and the outputs will be analysed. Due to the type of prototype, no materials or costs need to be allocated for the testing, since all the collected data is analytical.

<b>When?</b>	There are no dependencies to perform this test, as this is only a subsystem prototype. The focus remains on making the product easy-to-use and capable of helping users. All the testing for this reaction took roughly 30 minutes. During this time, various inputs and outputs were analysed using the program, and compared with the expected results.
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The testing phase of this subsystem was quite simple. The game was run, and the player began a distance away from the help menu, facing away from it. Then, the player was turned and then teleported to the landing spot. The help menu was found to be clearly legible from the teleport landing. However, a problem arose when testing this subsystem, as the player fell through the floor when the game was simulated. However, this problem was fixed by changing the floor material.

Overall, the test phase of the help menu subsystem was an overall success, as it was found to be easily accessible and clearly visible and legible from the teleport location.



## Testing Further Research into Student Quizzes and Progress

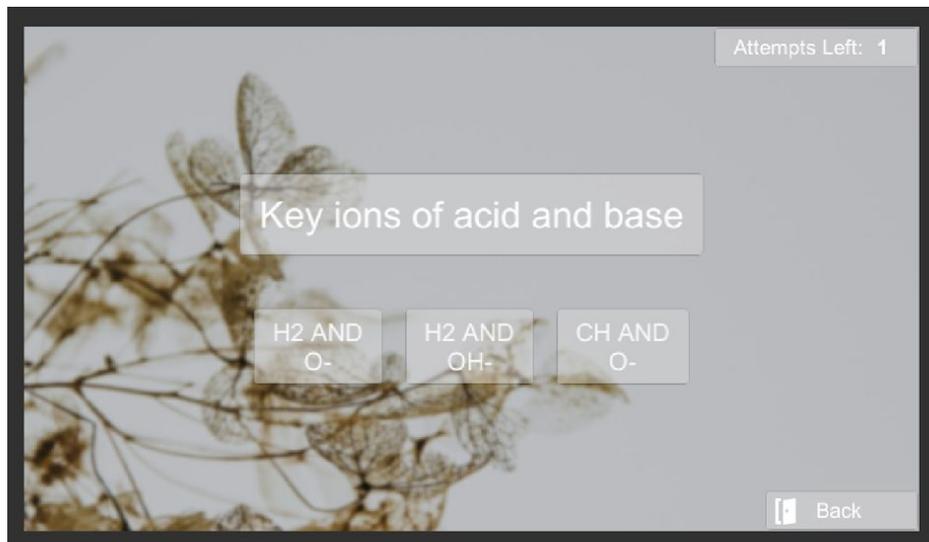
Testing analytically focused prototypes is different from conventional physical prototypes. However, in this case, since a program has been created, it is possible to test the inputs and outputs of the program.

Below are the questions that must be asked before and after testing the student quizzes and progress menu; this is to ensure that the testing is beneficial, and that substantial progress is being made.

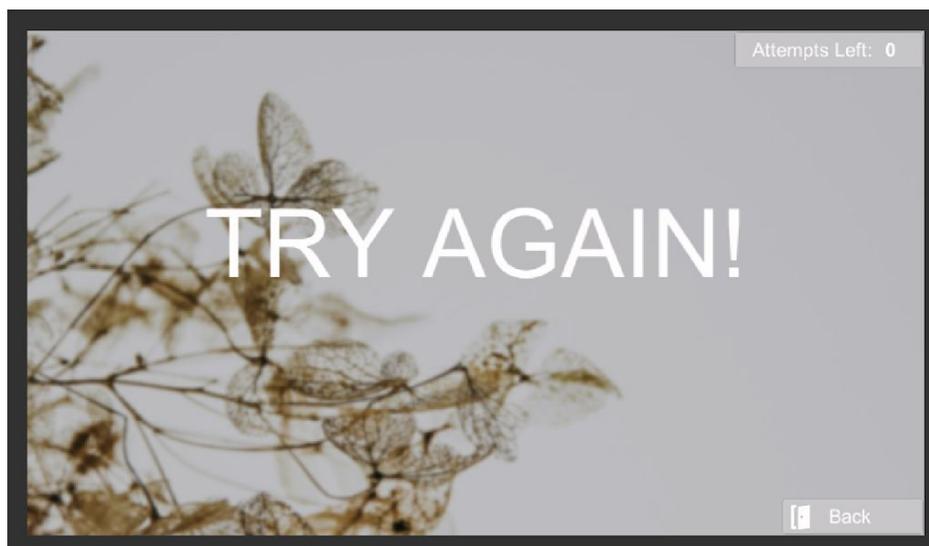
<b>Why?</b>	The purpose of this testing is to confirm that the features effectively output the necessary information to users. As stated earlier, customer feedback is the main goal of this prototype. The results of this testing will determine whether the team needs to recode the program or to reconvene with the client. For this test to be considered a failure, the program will not output the correct information to the user.
<b>What?</b>	The prototype type that is being tested is “analytically focused.” As stated, there are very few measurable attributes for this subsystem prototype. To test this prototype, various inputs will be provided for the code and the outputs will be analysed. Due to the type of prototype, no materials or costs need to be allocated for the testing, since all the collected data is analytical.
<b>When?</b>	There are no dependencies to perform this test, as this is only a subsystem prototype. The focus remains on making the product easy-to-use and capable of tracking student progress. All the testing for this reaction took roughly 1 hour. During this time, various inputs and outputs were analysed using the program, and compared with the expected results.

There is a very simple procedure when testing the quiz system. As this is only a coded software, only the inputs and outputs need to be analysed. In this case, the output of the program is displayed on the console and the user’s inputs are then evaluated. Once the user selects an option on the console, the program can continue, and that output will then be evaluated.

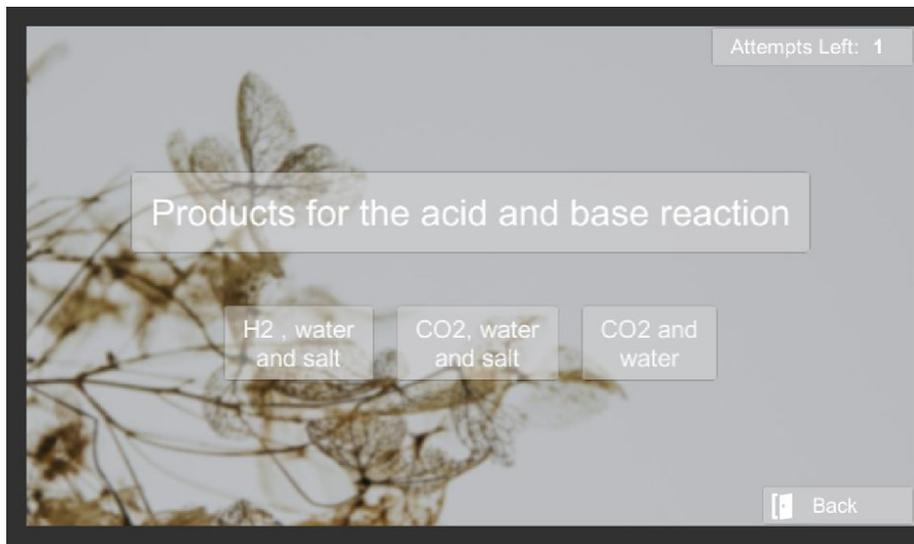
Below are screenshots of the console once the program has commenced. These screenshots represent the output of the software once the user provides an input. With these screenshots, the design team can analyse the outputs of the code and determine whether it has outputted correctly. The output testing will also help the design team determine if they can continue improving the subsystem, or whether new methods and technologies need to be used.



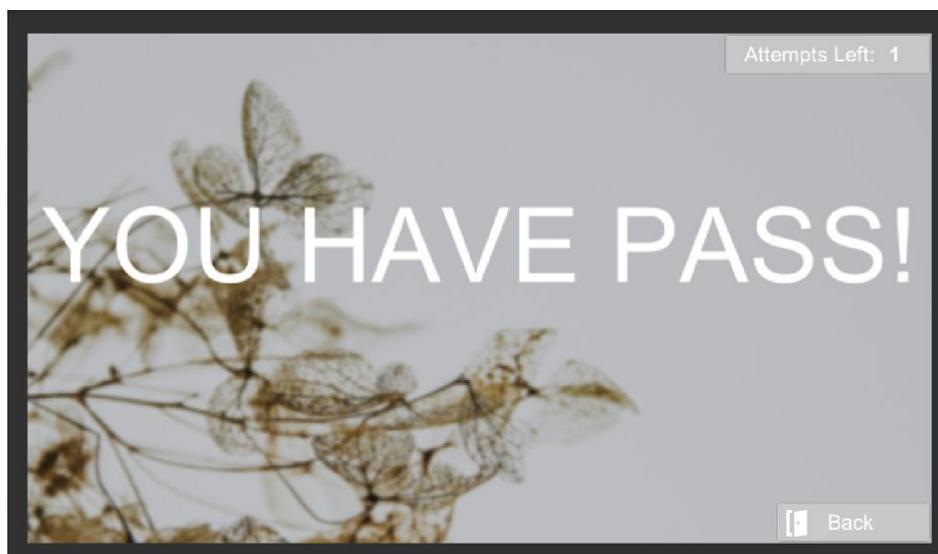
This is the format in which the questions will be provided to the user. It is important to note the “attempts left” queue and the back option. These features were designed to maximize user experience.



This screenshot is presented to the user if they have made an error. The professor will determine the number of attempts students have to answer questions.



Once again, this is the output presented to the user when a new question is available.



This screen is presented to the user once they have successfully answered the required questions and can proceed to the chemical reactions.

Once the testing of this prototype was completed, it was found that the subsystem functions properly and efficiently. The program outputs the correct information at the correct times, which was the biggest uncertainty for this subsystem. Now that the testing is completed, the design team will begin implementing this prototype into the global system.

## Modeling Phase

Another important aspect of prototype testing is modeling. A model refers to using mathematical or physical prototypes to simulate and analyse systems, entities, or processes. Modeling can help reduce costs, increase the quality of products, and makes it easier to document lessons learned. By creating models, the design team will be able to see the strengths and weaknesses of the product quantitatively and qualitatively. With these results, the design team will have the chance to improve the product and ensure that it meets all the client's needs.

Below are the distinct types of models, when they are used, and how they are used. There are three general modeling techniques in engineering design.

Type of Model	When is it Used?	How is it Used?
Analytical	Whenever a closed-form solution to the problem exists and the solution procedure is straightforward.	Using simple math equations and algebraic functions to find closed-form solutions to a problem. These solutions are then used for further analysis.
Numerical	When no closed-form solution exists, or the solution procedure is too complicated.	With mathematical representations that use discretization to approximate a solution. These complex models usually include many parameters and simulations.
Experimental	When no mathematical solution exists, or the problem requires too much time to solve computationally.	Creation of physical representations that study the input and output of the model. These results are then analysed to determine the strengths and weaknesses of a solution.

The design team will decide on which modeling technique to use based on the criteria and basic procedures listed above. Once the technique has been selected, the necessary tests will be run, and the results will be recorded for further analysis.

For this deliverable, the design team will be creating an experimental model. A "physical" representation of the product will be generated and researched, for further analysis. It must be noted that since the product is software, no "physical" model can be created. Although this experimental model will not be conventional, the strengths and weaknesses of the product can still be determined with the use of various inputs and outputs.

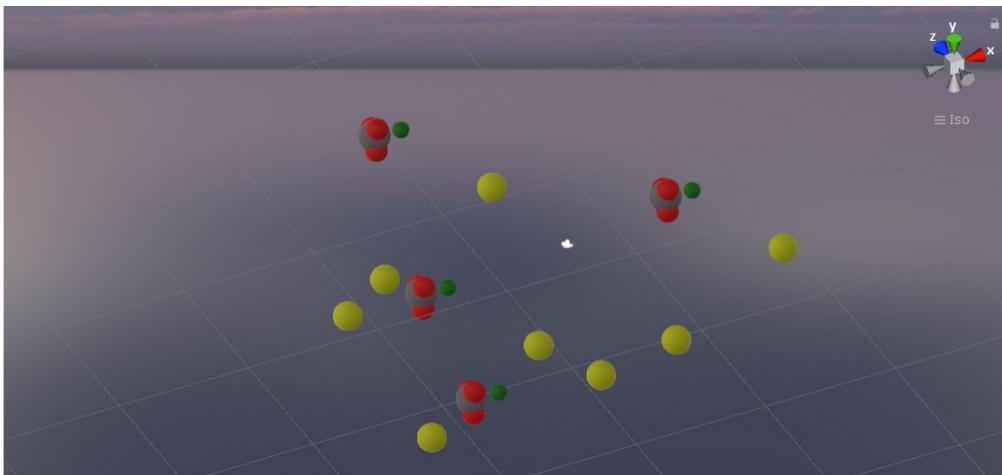
For this prototype, the molecular movement will be modeled. This was done to ensure that the structures' movement and collisions are accurate and stable. The design team will be analysing the output of the software when the chemical reactions are initiated. To successfully model this subsystem, screenshots of the molecules were taken at various stages of the reaction, like the testing phase. However, for modeling, the goal is not to determine whether the prototype is functional, it is to analyse the subsystem.

Before discussing the results of the modeling phase, it must be noted that the design team had to make several assumptions. It is important to address these assumptions before the design team ignores some intricate details. These assumptions can effectively save the design team a lot of time and effort.

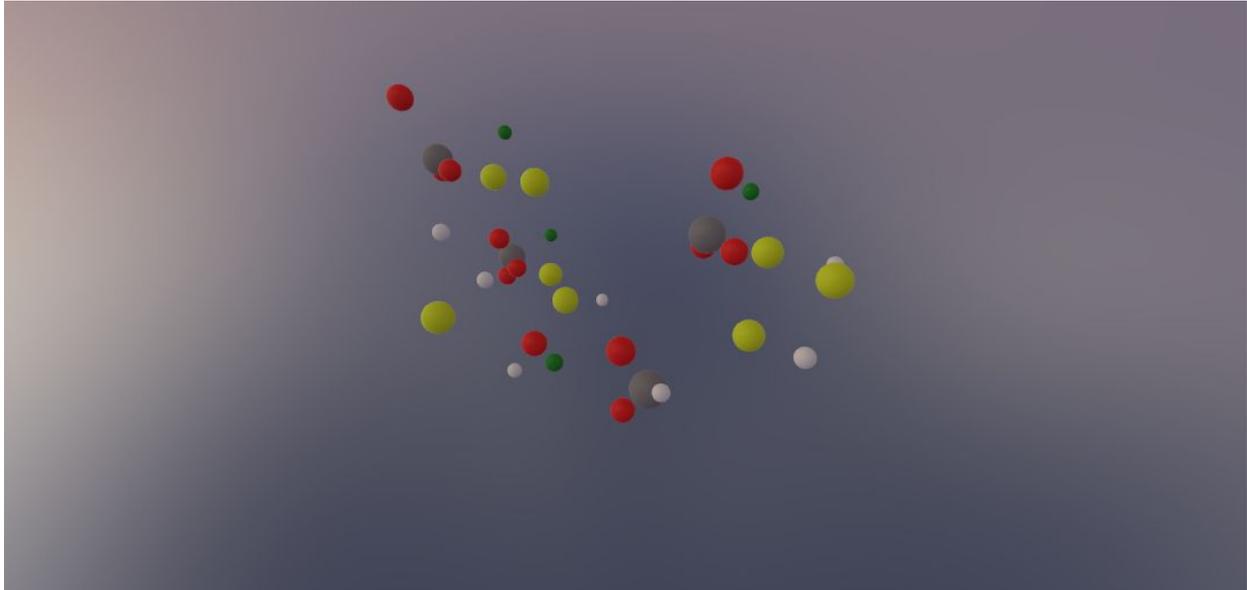
The first assumption was that the molecules do not need to obey the laws of gravity. Although this may seem like a significant fault in the product's physics, the electric forces between the molecules are significantly larger than the gravitational forces that are acting on them. By making this assumption, the design team can save some time by not needing to account for a constant downward motion, as well as the intermolecular movement.

The second assumption was that a smaller test group of molecules can effectively be used to represent a larger group. By creating only a quarter of the planned molecules for this modeling phase, the design team saved a lot of time and effort. The assumption is that the intermolecular forces will be identical no matter the scale of the reaction. By making this assumption, the design team can determine whether the reaction is accurate before creating countless molecules.

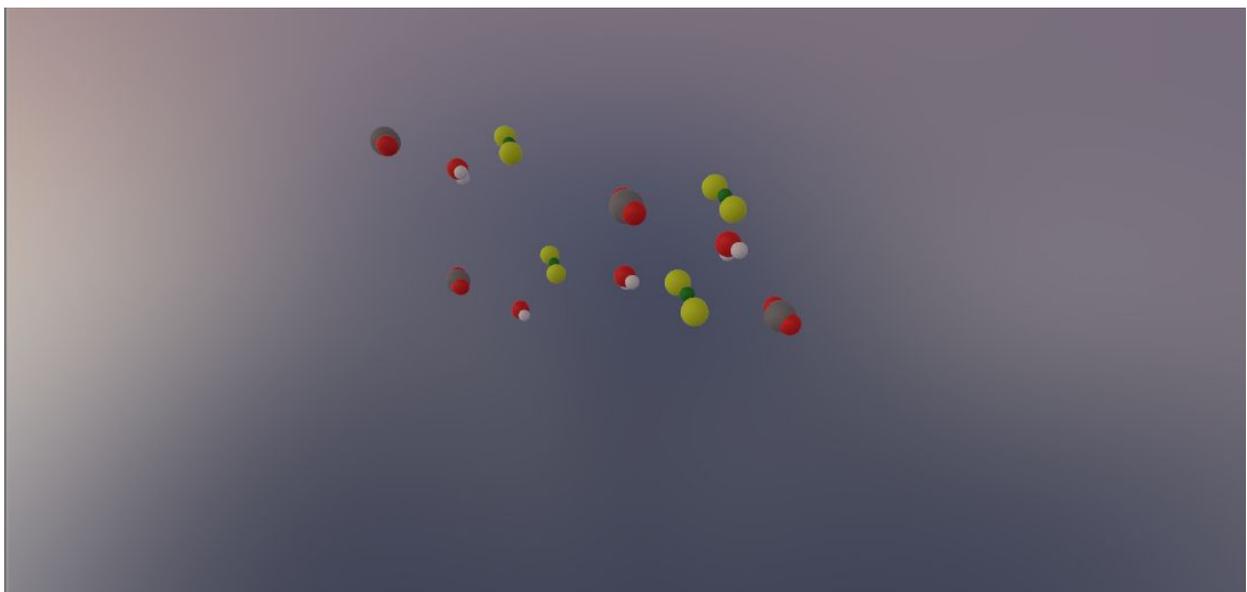
To begin with the modeling, the reaction is initiated, and the design team analyses the reactants. At this stage, the design team is observing the initial conditions of the reaction, ensuring that they accurately portray the real-world chemical reaction.



For the next stage, where bonds are broken and formed, the design team is looking to confirm that the atoms are colliding correctly and forming proper bonds with other atoms. At this stage, the team is analysing the path that the molecules follow, to ensure that it is accurate and stable.



For the final stage, where only the products remain, the design team is observing whether the correct molecules formed and whether they are oriented correctly. Once this observation and analysis period is completed, the design team determines that the chemical reaction, on the microscopic level, is accurate and effectively displays the various reaction stages.



Now that the modeling of this subsystem is complete, the design team has effectively managed any risks or uncertainties surrounding the prototype. As well, since the team does not need to further analyse this subsystem, the goals of the experimental modeling process were achieved.

## 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 many opinions 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.

During the third client meeting, the design team received some useful feedback regarding the second prototype. Firstly, the client was quite pleased with the global concepts that were presented and believes that they can genuinely help students learn organic chemistry. The primary advice that the user provided was to remove the second reaction altogether. Rather than the design team splitting its time between two reactions, the client requested that only one reaction be completed. As well, the client provided some minor cosmetic feedback that could be implemented in later prototypes. An example that the client gave is the colour of atoms; the design team must remain within international chemistry conventions.

For some more potential user feedback, a first-year organic chemistry student was consulted. Since this is the target user, it was crucial to receive this feedback. Only the environment and a short clip of the reaction were shown to this user. From this feedback, the design team can decide whether to continue improving these subsystems or to research innovative technologies and methods. Firstly, the student stated that they liked how realistic the environment looked and admired the attention to intricate details. As well, the student also liked the simplicity and organization of the lab, claiming that it would be too cluttered with any more prefabs. The chemistry student also said that they liked the interpretation of the chemical reaction and how it is different than what is usually taught.

With the feedback from the main client and a target user, the design team has a few minor changes to make. Overall, however, the design team has made substantial progress and soon plans to improve several subsystem prototypes.