

Prototype I and Customer Feedback

For this deliverable, the design team has created the first prototype for the virtual reality system. The goal of this prototype is to ensure that the team's ideas are attainable, denoting that the researching and brainstorming phase has been completed. Since this is a preliminary prototype, cosmetics and other unnecessary details will be disregarded until later stages. 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.

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.

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 first prototype will be both physically and analytically focused. This means that only the subsystems of the product will be prototyped. Physically focused means that a physical subsystem will be generated, and its performance will be measured before it is included in the general system. Analytically focused means that more math and science will be generated and analysed for the subsystems; these analytics will then be implemented in later prototypes.

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 and Macroscopic Models
- Various Unity and Interfacing Methods
- Chemical Reactions
- Help Menu
- Quizzes and Student 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 should 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 Molecular and Macroscopic Models

To prototype the molecular models that will be used during the reactions, a large amount of shape construction and geometry must be used. Using skills acquired in the lab and with online Unity tutorials, the molecular structures could be generated. To begin with, no physical prototypes were created; they were only generated using software. This is beneficial to the design team because the molecular structures that will be used in the global system are all software. Instead of using time and effort to create physical models that will not be used, computer-built atoms were made.

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.

Prototyping Questions	Response	Brief Explanation
Purpose of the prototype?	To get user feedback and to maximize scientific accuracy	By going in-depth into the details of the molecular structures, 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 simulated models still represent physical chemical structures.
How will it be generated?	By consulting several Unity 3D shape tutorials and lessons from the lab	Several Unity tutorials for 3D shape building were consulted when producing the chemical structures. Lessons learnt in the lab were also used when prototyping the chemical structures. By taking advantage of these resources, the design team was able to create the most accurate molecules possible.
Materials needed?	Unity software	The Unity software was used to create the structures and was the only “material” needed.
Cost to produce?	None	There was no cost needed to produce this subsystem prototype.
Time constraints?	2 days	Two days were needed to build the models. The models could not have been created until the chemical reactions were chosen and researched.

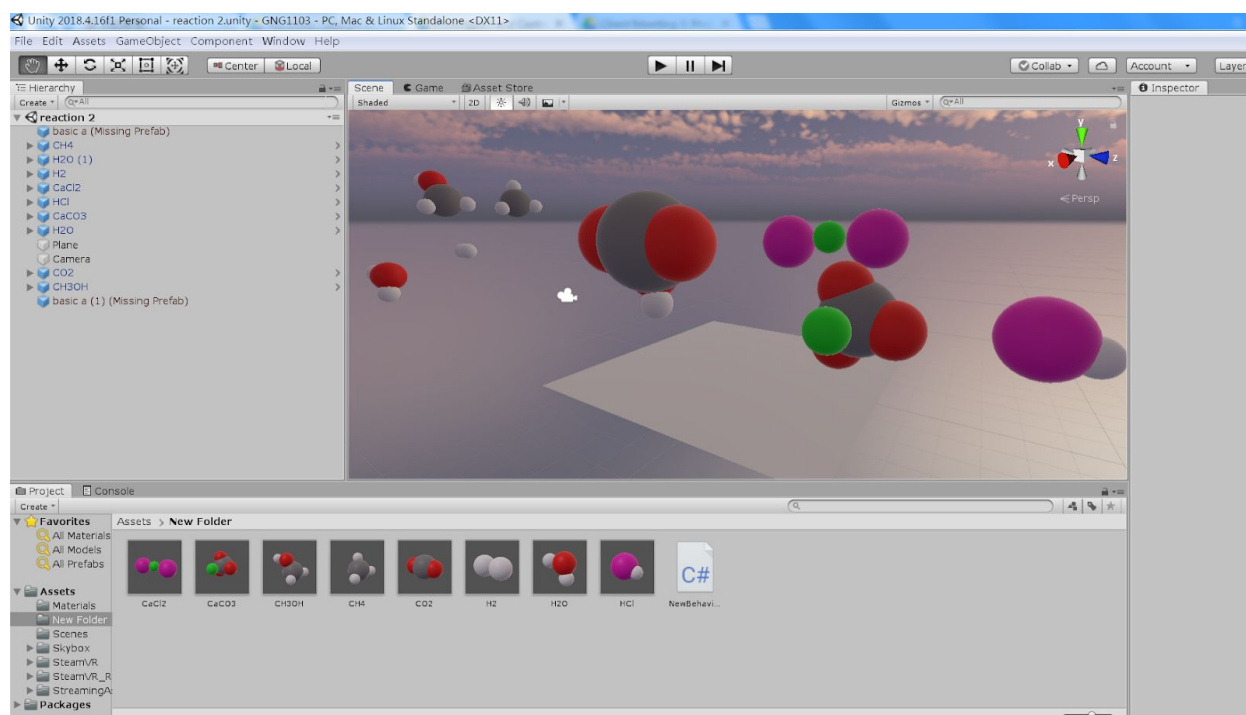
For this preliminary prototype, molecular models were generated to represent all the participants in the reactions. Using Unity’s 3D object builder, the molecular structures were built and oriented. To guide the design team during this process, an organic chemistry textbook and several internet resources were consulted.

There were some special considerations when creating these models. Atom size, molecular proportionality, and atom colour were all considered. For atom size and proportionality. Previous chemistry knowledge was used, along with an online resource. Generally, atoms with large molar masses are going to be larger than atoms with smaller molar masses. An example that can be seen in the image below is HCl. The

Chlorine atom (pink) and a Hydrogen atom (white) are not the same size; chlorine has a significantly greater molar mass than hydrogen. This relationship was used to determine relative atom size in a molecule.

This relationship was also used for molecules. Molecules with large molar masses will be larger than molecules with smaller molar masses, exactly like atoms. An example below is HCl and H₂, HCl has a significantly larger molar mass than H₂, so its molecule will be much larger too.

To remain scientifically accurate, the atomic colours obeyed international regulations. This was done to ensure that the VR system is renowned and usable internationally. Another example seen below is Oxygen; red atoms are usually allocated to oxygen, which makes them recognizable internationally.



With these models completed, the design team can continue progressing and creating scientifically accurate reactions. Now that the molecules have been generated, the team can begin using translations and rotations to accurately portray the molecules' tendencies during chemical reactions. For the following prototypes, these models will be used constantly, so it was important to complete them properly and promptly.

Prototyping Various Unity and Interfacing Methods

To prototype the coding and interface methods that will be used in the VR system, a lot of research and analysis must be conducted. By watching countless online tutorials and using previously known programming information, research was conducted on the best techniques to effectively solve the user's problems. Firstly, no physical subsystems were generated for this prototype; only research and analysis were conducted. It is crucial to clearly understand the required coding and VR techniques before creating further prototypes. This will save the design team a lot of time, money, and effort when all the subsystems are being put together.

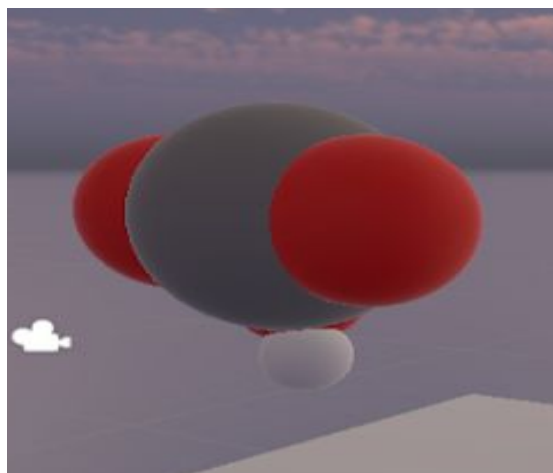
As seen below, several questions are to be asked when prototyping the subsystems, to ensure that the design team is aware of the component's objectives.

Prototyping Questions	Response	Brief Explanation
Purpose of the prototype?	For further analysis and to reduce uncertainty.	By researching the many possible techniques that could be used to solve the user's problems, the design team can make the VR system sound and easy to use, 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 research was conducted to ensure crucial Unity techniques are thoroughly understood and implemented.
How will it be generated?	By consulting many online tutorials and previously known information	Many YouTube videos and Unity tutorials were consulted for this prototype. This was done to research the various techniques that could be implemented into the VR system. Various coding techniques that would be applied in Unity were considered for this prototype. By acquiring a greater understanding of Unity, it will be easier to apply these techniques in future prototypes.
Materials needed?	None	Since this is an analytically focused prototype, no materials are needed.

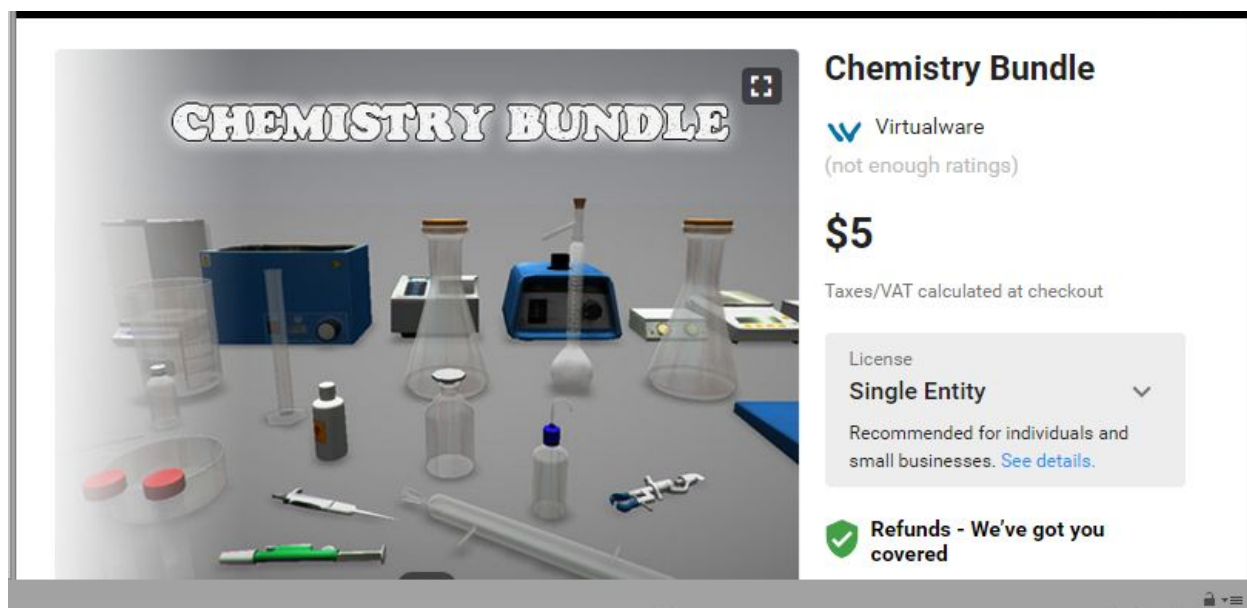
Cost to produce?	None	Since this is an analytically focused prototype, there are no production costs.
Time constraints?	6 hours	6 hours were needed to conduct the research and run the required tests.

For this prototype, the design team conducted research on various techniques that could be implemented in the product. Whether it would be cosmetic, VR specific, chemistry specific, or a bit of everything, research was conducted.

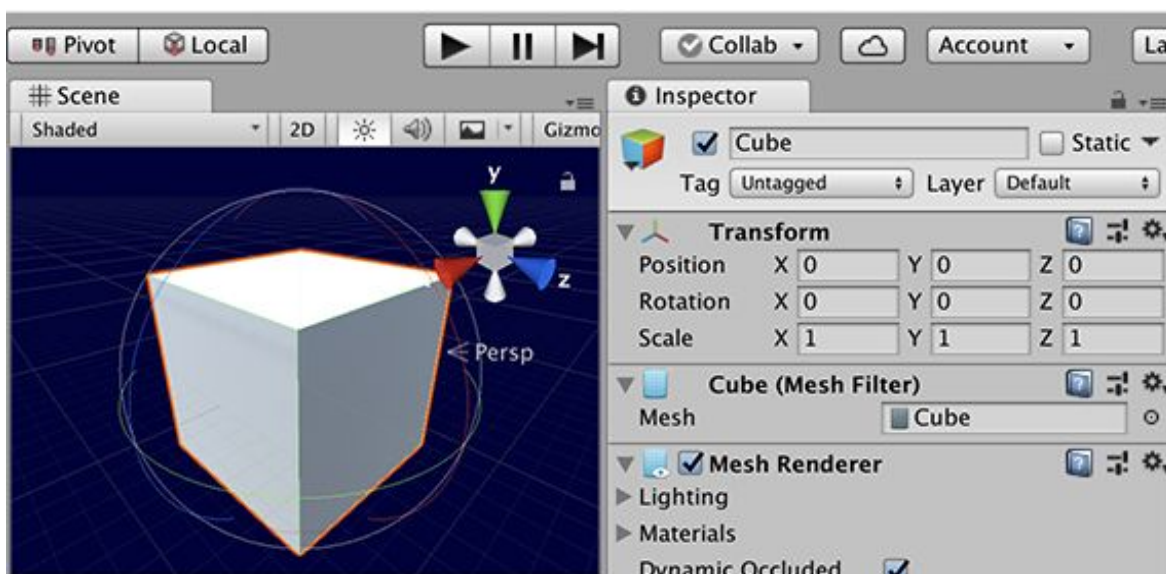
Firstly, cosmetics were vaguely researched for this prototype, as the design team is still in early stages. For this research, the asset store and the work of others were consulted. The first cosmetic that was prototyped was the colour of molecular models. Solid colours, gradient paint style, and textures were considered and tested. Although this “testing” is more opinion-based, it still helped the design team choose an option. Once testing was done, discussed in further detail later, the team decided that solid colours would be ideal. This option was chosen to remain in accordance with international expectations and for the sake of simplicity. An example of a solid colour molecule that will be used for the rest of this project can be seen below.



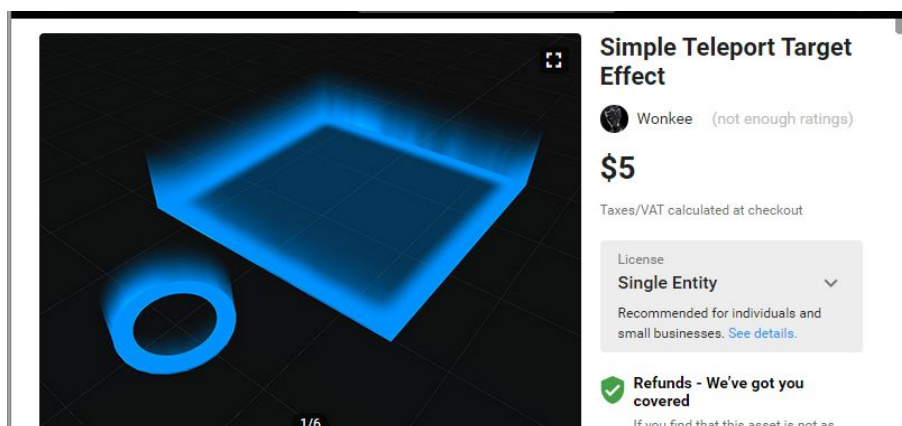
The other cosmetics that were considered were chemistry specific, more specifically for the macroscopic level. For this level of the reaction, a real-world interpretation for the reaction would be required. To ensure that the macroscopic level looks realistic, glassware and other essential chemistry equipment would be needed. It would be too difficult to build these, so the design team decided to consult the Unity asset store. After reviewing several products and testing them, in more detail later, it was decided that *Chemistry Bundle* would be used. Below is a screenshot of the asset store purchase that will be used for the remainder of this project.



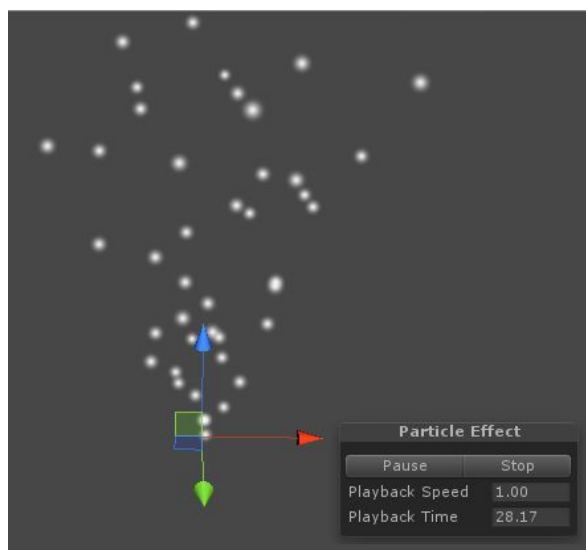
For the next part of this prototype, VR specific techniques were researched using several YouTube videos. The main topics that were researched include object translation and teleportation. Both techniques are planned to be implemented in later prototypes; therefore, it was important to accurately research the techniques early on. For the first part, object translation was thoroughly researched and tested using YouTube videos and Unity. Using vector movement, automatically implemented, it is possible to make the chemical models move. It was also learnt that the speed, lifespan, and direction of motion can be altered. Below is a picture of the menu that will be used to translate and rotate the chemical molecules. With this information the design team can move forward in the project and begin constructing chemical reactions.



Teleportation was the next technique that was researched, and it was slightly more complicated. The design team needed to decide whether purchasing an asset or coding a solution would be ideal. Special considerations were made to cost, time constraints, easiness. Once the techniques were consulted and tested using YouTube and Unity once again, it was found that an asset would be easiest and save a lot of time. Below is a screenshot of the asset which will be used in later prototypes.



For this final part of this prototype, chemistry specific techniques were researched. In this prototype, the only technique that was researched was the “particle effects.” This is a collection of “particles” that are released from a certain point, like a gas rising. This technique will be used for the macroscopic level of the chemical reactions, to represent gas leaving a beaker or flask. Very little research was needed for this technique, as it is already embedded in Unity. Only YouTube tutorials were consulted, to know how to operate the system. Below is an example of the technique that will be used in future prototypes.



Now that the research has been conducted on basic cosmetics, Unity techniques, and chemistry specific methods, the design team can continue its progress and begin creating chemical reactions.

Prototyping Chemical Reactions

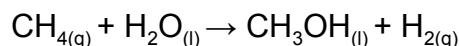
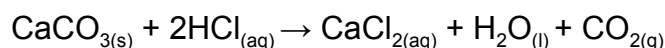
To prototype the chemical reactions that will be performed using the virtual reality system, a large amount of math and science must be used. Using skills already known by the design team, and several other resources, both reactions were thoroughly studied. Firstly, for this prototype, no physical reactions were performed or generated, they were only analysed. Rather, the simulations of these reactions will be generated in later prototypes; this was done to save time, money, and to ensure that the reactions are suitable for the client's needs.

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.

Prototyping Questions	Response	Brief Explanation
Purpose of the prototype?	For further analysis and to maximize scientific accuracy	By going in-depth into the details of the reactions, the design team can make these reactions as accurate as possible, 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 ensure crucial reaction data was collected, without wasting time on performing the reactions ourselves.
How will it be generated?	By consulting several internet resources and previously known information	Many YouTube videos of the reactions were consulted; this was done to verify the macroscopic interpretation of the reactions. For the microscopic components of the reactions, many chemistry resources were consulted. These resources provided reactions speeds, sizes of molecules, rates of reactions, and other crucial information.
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?	1 day	One day was needed to conduct the research and run the required tests.

For this prototype, reaction data was found for the following chemical reactions:



Reaction 1 will look at the effects that macroscopic changes (ex. adding another reactant) have on the microscopic level (ex. speeds of molecules). Firstly, this reaction was chosen to prototype because of its simplicity. There are very few reactants and the macroscopic effects are easy to visualize for most first-year organic chemistry students.

The general attributes of this reaction indicate that a precipitate is formed once the reaction concludes. This precipitate (aqueous solid) is formed from the CaCl_2 and H_2O by-products.

On the macroscopic level, this is the order of events, as seen in many YouTube videos:

1. A transparent solution of HCl is in the beaker
2. Solid CaCO_3 is then added
3. The solution begins to bubble and turn an opaque white
4. Some CO_2 gas escapes
5. CaCl_2 precipitate and liquid H_2O remain

This information is crucial to accurately display one portion of the reaction.

On the microscopic level, more research was needed. Several online resources such as PubChem and ChemSpider were consulted for data, along with previously known information.

To begin, HCl molecules are crowded together approximately $1.27\text{E}-27\text{m}$ apart, the typical distance for liquids. At this point as well, the HCl molecules are moving at a “medium” speed, for context, similar speed to water molecules.

Once solid CaCO_3 is added, the volume of the solution rises. The calcium carbonate molecules are much closer together than those of HCl, since CaCO_3 is a solid. The speed of the molecules is also much slower than those of HCl molecules, once again, because it is a solid.

When the reaction goes to completion, CO_2 gas escapes the container. The CO_2 molecules are very far apart and are travelling at immense speeds compared to solids and liquids. The H_2O and CaCl_2 that remain travel at “medium speed,” as described earlier. Like HCl at the beginning of the reaction, these molecules are close together and tend to remain at the bottom of the beaker.

An important detail that must be considered for this reaction is that an equal number of molecules of CaCO_3 , CaCl_2 , CO_2 , and H_2O must be found in the beaker. Uniquely, HCl must have double the number of molecules compared to those just listed, according to the balanced chemical equation.

Reaction 2 will look at the effects that microscopic changes (ex. speeds of molecules) have on the macroscopic level (ex. adding another reactant). Firstly, this reaction was chosen to prototype because it is very simple. There are only two reactants and the microscopic impacts are easy to comprehend for most first-year organic chemistry students.

The general attributes of this reaction indicate that a phase change takes place once the reaction concludes. This phase change occurs when methane gas (CH_4) undergoes a hydration reaction.

On the macroscopic level, this is the order of events, as seen in an organic chemistry textbook:

1. Methane gas molecules are sealed in a container
2. Liquid water is added to the container and the container is heated
3. The solution begins to smoke and liquid forms at the bottom of the container
4. Some H_2 gas escapes
5. Methanol in liquid forms remains

This information is crucial, as it allows users to see the effect that microscopic changes can have on a system, like a phase change.

On the microscopic level, very little research was needed. Only prior organic chemistry knowledge and an online organic chemistry textbook were consulted for reaction information.

To begin, CH_4 gas molecules are spaced out at extreme distances, approximately $4.0\text{E}-29\text{m}$ apart, the typical distance for gases. At this point as well, the CH_4 molecules are moving at a “very high” speed, for context, much faster than water molecules.

Once liquid H_2O and heat are added, a hydration reaction takes place. The water molecules are much closer together than those of CH_4 since H_2O is a liquid. The speed of the molecules is also much slower than those of CH_4 molecules, once again, because water is a liquid.

When the reaction goes to completion, H_2 gas escapes the container. The H_2 molecules are very far apart and are travelling at immense speeds, like those of CH_4 . The CH_3OH that remains travels at “medium speed,” like the water that was added at the beginning of the reaction. Also, like H_2O , the CH_3OH molecules are close together and tend to remain at the bottom of the beaker.

Prototyping 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. This program will be implemented in later prototypes once the subsystems have been put together.

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.

Prototyping Questions	Response	Brief Explanation
Purpose of the prototype?	Getting user feedback	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 on.
How will it be generated?	Using previously known information	Using knowledge acquired in past courses, the design team was able to create 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?	1 day	One day was needed to create the program and run the required tests.

When programming a help menu, the focus is to consider user accessibility. If the help menu is difficult to find or use, then it is not successful in assisting the user. To create a successful help menu that would assist the user as much as possible, two main concepts were considered: accessibility and content.

To maximize the accessibility of the help menu, the design team found that it was best for the help menu to constantly be close to the player. Thus, a constant teleport location would be located at the back of the room in which the user is performing the experiment. To use a teleport location in virtual reality, the user simply must point their hand to a point on the screen where teleport is possible and press a button on the controller. When the help menu location is teleported to, a portion of the screen will show text directly in front of the user. By ensuring that the help menu is visible from the reaction site and can easily be located (and subsequently teleported to), it is easier for users of all levels of VR experience to locate and use the menu.

Below is an example of an effective location for the help menu.

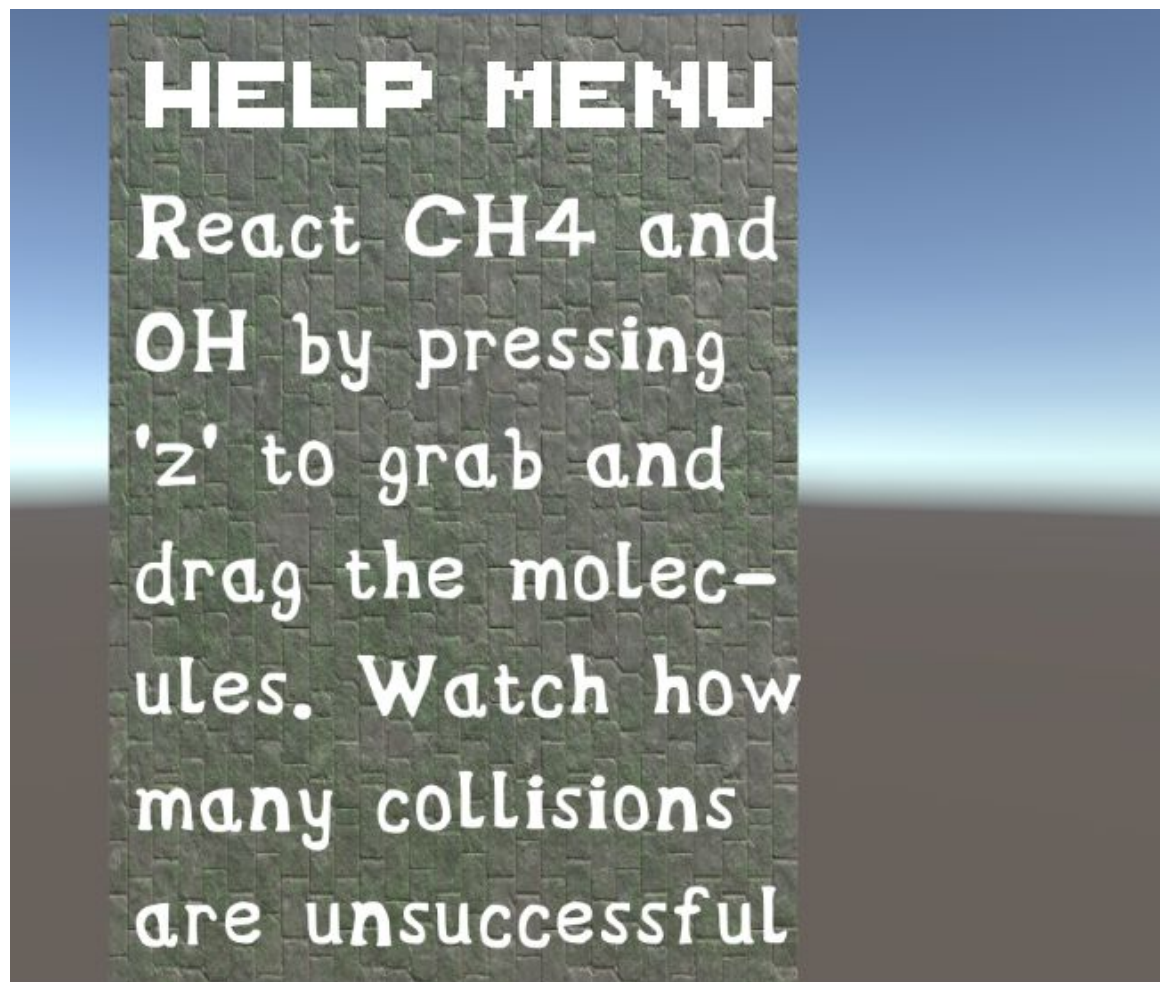
Help menu



Reaction

The content of the help menu that would provide the most helpful directions is also important. To help users with little virtual reality experience, the directions would direct which buttons to press on the controller at various times to accomplish certain tasks. For example, if a beaker must be picked up during a reaction, the help menu would instruct the user to move their hand adjacent to the beaker and press the trigger button on the controller. This instruction would prompt the user to achieve the basic functions of virtual reality.

Below is a screenshot of a potential help menu format.



In terms of the chemical reaction itself, the help menu would instruct users which molecules to react and what aspects of the chemistry to pay attention to as the reaction progresses. This provides a useful reference to users struggling to correctly complete a component of a reaction and serves to reinforce the concepts discussed in the pre-lab quiz.

One constraint on the help menu is in the brevity of the text. If the text is too long, it will not display full, necessary instructions on the help menu portion of the screen. Therefore, brief instructions are key to provide users with a full range of helpful instruction.

Overall, the help menu content would be best served if it provided instructions for virtual reality controls, reaction progression, yet kept those instructions brief enough to be displayed on a help menu screen.

Prototyping Quizzes and Student Progress

To prototype the quizzes and student progress, 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 have no physical form, only the input and output can be observed and analysed. This program will be implemented in later prototypes once the subsystems have been put together.

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.

Prototyping Questions	Response	Brief Explanation
Purpose of the prototype?	Getting user feedback	By creating this program to track student progress, the product will be more interactive. This will help track how effectively students are learning, 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 on.
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 teaches students.
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?	3 days	3 days were needed to create the program and run the required tests.

For this prototype, instead of using C#, the Python programming language is used since it is closer to human language, and it is easiest to read and comprehend.

Before each reaction, there are two related multiple-choice questions in a quiz that tests whether students are ready to perform the reactions. Once the students are ready, their metrics will be reflected in the students' progress menu.

Four elements have been set before running the question: *mark1* is the mark for the first question, and it is 100 initially; *h1* is the number of hints for each question and it is set to 1 since there is only one hint per question; *htn* is the number of times that the student uses the hints during the quiz; *wrn* is the number that represents the times that the student answered incorrectly during the quiz.

Each time a student gets a question wrong, it causes the mark to drop 30 points ($mark1 = mark1 - 30$), and the wrong number to increase by one ($wrn = wrn + 1$); the student has the choice on whether to use the hint in this case. If they choose to use the hint, it will be displayed and the hint chance will be used ($h1 = h1 - 1$), the hint number will add by one ($htn = htn + 1$) and take 10 points off ($mark1 = mark1 - 10$).

Below are screenshots of the Python code that will be used to generate student quizzes.

```
print('Which answer is correct? \nA. -----\nB. -----\nC. -----\nD. -----\n')
x=input()
mark1=100
h1=1 #h1 is the one because there is only one hint in each question
htn=0 #htn is the times that the user used the hint in the quiz
wrn=0 #wrn is the times that the user get the wrong answer
while x is not 'A' and mark1 >=30:
    mark1=mark1-20 #one incorrect choice will cause the mark of this question drop 20%
    wrn=wrn+1
    print('Your answer is wrong\n')

    if h1 >= 1 :
        hint=input('Do you want hints? Y or N\n')
        if hint is 'Y':
            h1=h1-1
            htn=htn+1
            mark1=mark1-10 # One hint will cost 10 percent off
            print('Think about.....')

    x=input('Please try again: ')
print('Correct')
```

```

print('Which answer is correct? \nA. -----\nB. -----\nC. -----\nD. -----')
x=input()
mark2=100
hl=1
while x is not 'C' and mark1 >=30:
    mark1=mark1-20
    wrn=wrn+1
    print('Your answer is wrong\n')

    if hl >= 1 :
        hint=input('Do you want hints? Y or N\n')
        if hint is 'Y':
            hl=hl-1
            htn=htn+1
            mark2=mark2-10
            print('Think about.....')

    x=input('Please try again: ')
mark=(mark1+mark2)/2
print('Your mark of quiz is ',mark)

```

Once the quiz questions have been completed, the results will be made available in the student progress menu. This menu will be generated in the next prototype.

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 it be analysed by the design team to improve the product?
- Interpret the results
 - What can be improved?

All these steps will be covered when testing the preliminary 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 be 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 and Macroscopic Models

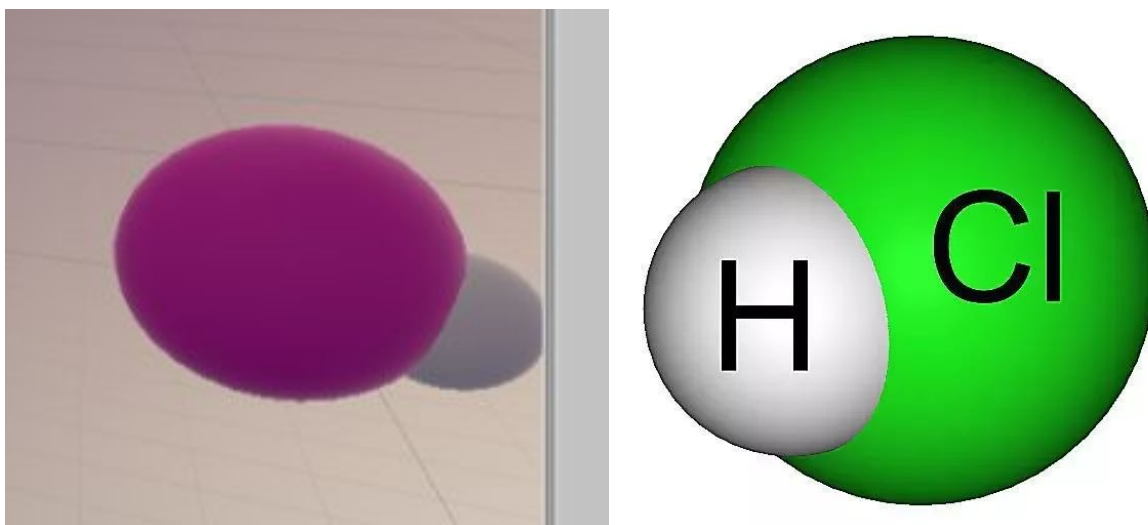
Testing “physically” focused software-developed prototypes is different from conventional physical prototypes. There are very few measurable performance quantities that can be measured, which makes the testing judgment, and trial and error oriented.

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

Why?	The purpose of this testing is to confirm that 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 redesign the molecular models or conduct further research. For this test to be considered a failure, the models would not coincide with those from other resources (found on the internet using simulations).
What?	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 structures 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, where the 3D structures were constructed.
When?	This prototype only had one dependency. Without the chemical reactions being chosen and analysed, this subsystem prototype could not have been created. Once the chemical reaction prototype was completed, this prototype construction and testing could begin. All the testing for this reaction took roughly 5 hours. 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 molecular structures, observation and comparison will be used to test the molecular structures. Especially in this case where the intricate details will not be significant, these tests will be crucial in determining whether the molecular structures are accurate.

To observe and compare the Unity-made models to those of internet resources, the molecular shapes and atom orientation must be deeply analysed. The example below compares the molecular structures of HCl and relative atom distribution from both Unity and the internet.



From the internet image on the right, it is seen that the Chlorine atom is much larger than the Hydrogen atom. This is also displayed on the Unity-generated molecule on the left; therefore, this aspect of the test was a success. Next, the image on the right states that the hydrogen atom is branched off the chlorine atom; this is also seen on the left, meaning that this aspect of the test was successful once again.

The prototype testing phase displayed that these molecular structures accurately portray chemical models, which was the goal of the testing. The next stage is to have these molecules translate, rotate, and take part in chemical reactions.

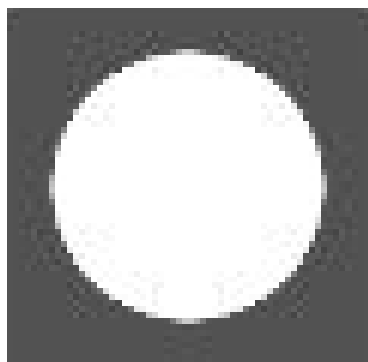
Testing Various Unity and Interfacing Methods

Testing analytically focused prototypes is different from conventional physical prototypes. There are very few measurable performance quantities that can be measured, especially in this case when only research is being conducted.

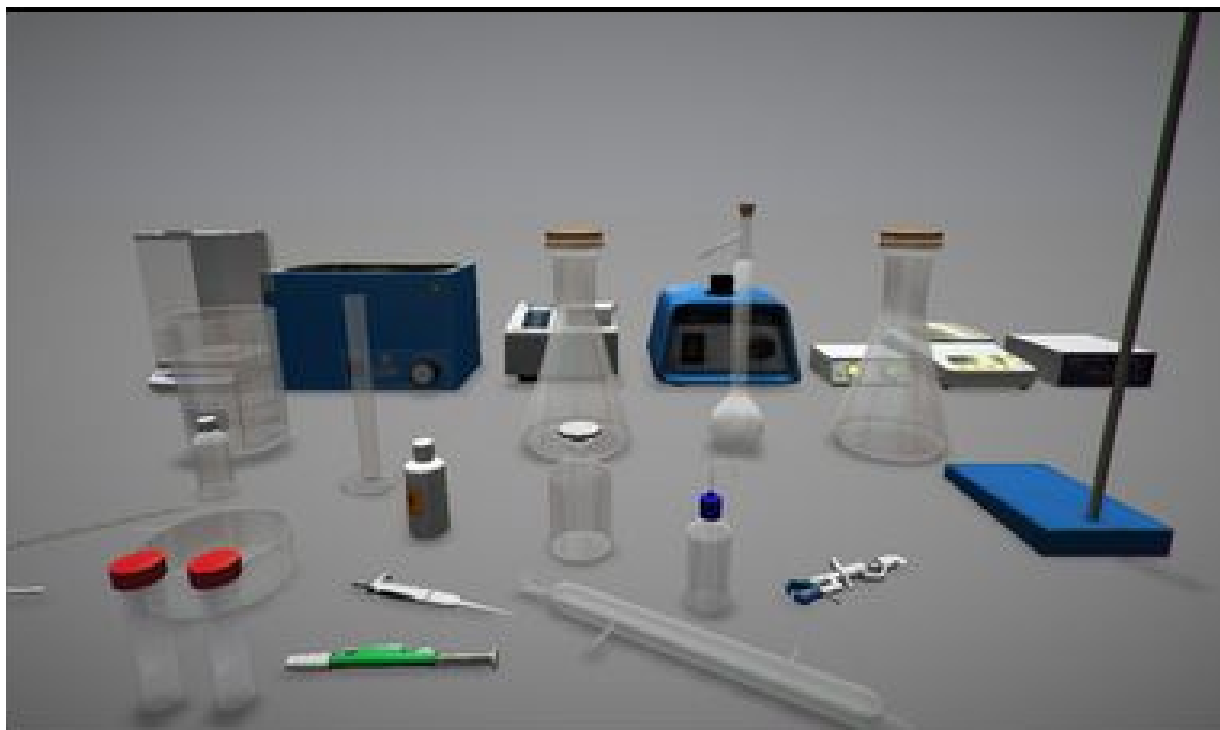
Below are the questions that must be asked before and after testing the chemical reactions; this is to ensure that the testing is beneficial, and that substantial progress is being made.

Why?	The purpose of this testing is to discover a variety of coding and Unity techniques that can be implemented in future prototypes. As stated earlier, further analysis and reducing uncertainty are the main goals of this prototype. The results of this testing will determine whether the team can move forward with implementing the acquired techniques or whether more research needs to be conducted. For this test to be considered a failure, the researched techniques would not work as planned, in comparison to those of other projects.
What?	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, the researched techniques will be compared with those of several online resources. Due to the type of prototype, no materials or costs need to be allocated for the testing, since all the collected data is research-based.
When?	There are no dependencies to perform this test, as this remains to be a preliminary prototype. The focus remains on creating a low-risk product that will make future prototypes easier to generate. 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.

For this first test conducted for this prototype, different colour styles and textures for chemical models were compared. Solid colours, gradient colours, and various textures were considered, but it was decided by the design team that solid colours would be the best choice. Below are screenshots of a Hydrogen atom with different cosmetic styles. In order from left to right: solid colour, gradient colour, and textured finish.

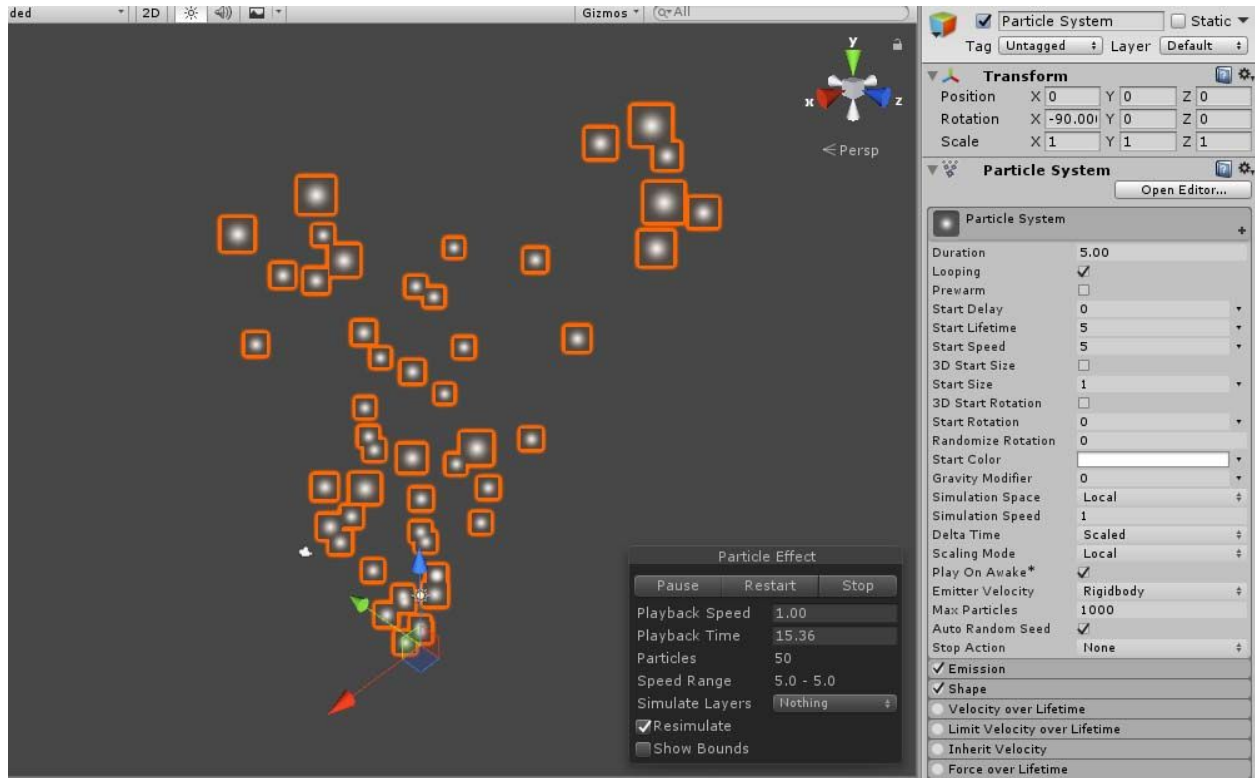


Next, the *Chemistry Bundle* glassware kit that will be used for macroscopic reactions was tested. For this test, the features of the bundle were inspected, and it was ensured that the contents of the asset fit the design team's needs. Below is a screenshot of the bundle and most of its glassware and chemical tools that were included.



For object translation and teleportation, no “tests” were performed. These techniques will be included in the next prototype; therefore, the design team did not apply the research that was conducted. However, with the many YouTube videos and Unity tutorials that were consulted, the design team is confident that these techniques can be implemented into the next prototype without performing its own extensive testing.

The final test that was performed for this prototype is the “particle effects” system. Unlike the above techniques, the design team did conduct personal testing, and the results were quite favourable. It was found that the particle animations strongly resemble those of gas particles escaping a beaker or flask. Below is a screenshot of this technique in action, along with the menu that will allow the design team to change speed and colour.



Once the testing of this subsystem concluded, it was found that all the trials were successful. The design team will begin implementing these cosmetics and techniques in future prototypes.

Testing Chemical Reactions

Testing analytically focused prototypes is different from conventional physical prototypes. There are very few measurable performance quantities that can be measured, which makes the testing judgment oriented.

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

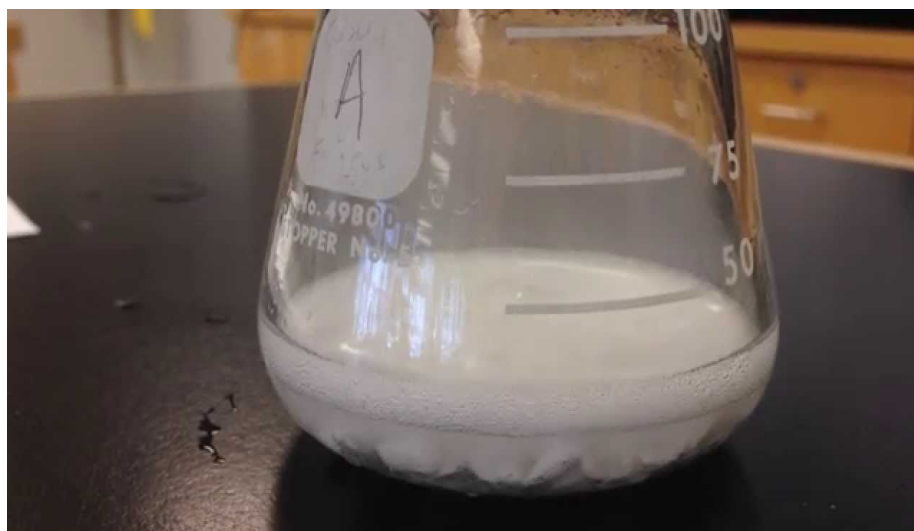
<p>Why?</p>	<p>The purpose of this testing is to confirm that the reaction data is accurate and can be implemented in the VR system effectively. As stated earlier, further analysis and risk prevention are the main goals of this prototype. The results of this testing will determine whether the team needs to select new reactions or continue conducting more research. For this test to be considered a failure, the reaction data would not coincide with those of actual reactions (found on the internet using simulations).</p>
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What?	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, the reaction attributes will be compared with those of several online resources. Due to the type of prototype, no materials or costs need to be allocated for the testing, since all the collected data is analytical.
When?	There are no dependencies to perform this test, as this remains to be a preliminary prototype. The focus remains on creating a low-risk product that is scientifically accurate, so this stage requires a lot of attention and minimal time constraints. All the testing for this reaction took roughly 2 hours. During this time, several videos and tutorials were analyzed for an in-depth comparison with the prototype.

Once the testing was conducted and data was collected for **reaction 1**, it was found that all the reaction data was accurate. After watching several YouTube videos of the reaction, the macroscopic interpretation of the reaction was found to perfectly coincide with the generation of the prototype. Everything from colour changes to precipitation formation was accurate, therefore the macroscopic test was a success.

For the microscopic interpretation of the reaction, VisiChem, a 2-D reaction simulator was used to test the prototype. It was found that the prototyping data correlates with the reactions in VisiChem. Reaction speed, distance between molecules, and molecular phases were all extremely accurate. Therefore, this analytical test was a success.

An example of a resource that was consulted for this reaction is a screenshot of a video seen below.

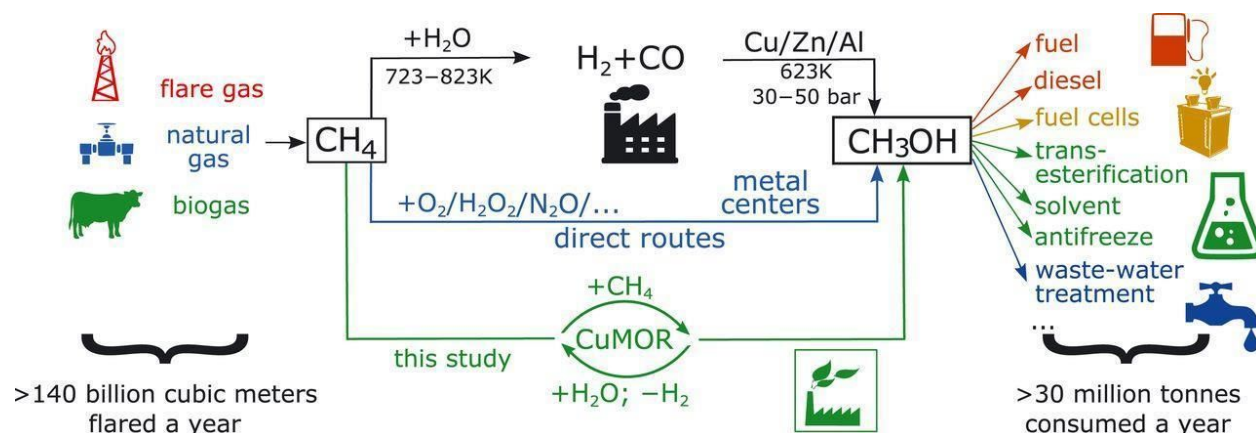


After conducting the required tests, the prototype requirements met those of other resources. This means that the design team can proceed with this reaction and begin to implement it into Unity.

For **reaction 2**, once the testing was conducted and data was collected, it was found that all the reaction data was accurate. After consulting an organic chemistry textbook and a few online resources, the microscopic interpretation of the reaction was found to perfectly coincide with the generation of the prototype. Everything from molecular speeds to distances between molecules was accurate, therefore the microscopic test was a success.

For the macroscopic interpretation of the reaction, some YouTube videos were used to test the prototype. It was found that the prototyping data correlates with the reactions performed in a professional chemistry lab. Chemical changes, phase changes, and smoke forming in the beaker were all extremely accurate. Therefore, this analytical test was a success.

An example of a resource that was consulted for this reaction is an image seen below.



After conducting the required tests, the prototype requirements met those of other resources. This means that the design team can proceed with this reaction and begin to implement it into Unity.

Testing 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 chemical reactions; this is to ensure that the testing is beneficial, and that substantial progress is being made.

Why?	The purpose of this testing is to confirm that the help menu effectively outputs 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.
What?	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.
When?	There are no dependencies to perform this test, as this remains to be a preliminary 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.

When testing a help menu the overall process consists of setting a makeshift scene and testing the amount of help the menu provides, as well as how accessible the menu itself was. This testing process was extremely simple, as it consisted of a single scene.

In completion, the help menu located behind the player, in the corner of the room was found by the design team to be an ideal location. The player’s ability to simply teleport a short distance to a visible object that displayed all the key information was proven to be extremely helpful, as it allowed a great deal of information to be found

easily. Therefore, the help menu located behind the user showing both controls and reaction instructions was used.

Testing Quizzes and Student 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 chemical reactions; this is to ensure that the testing is beneficial, and that substantial progress is being made.

Why?	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.
What?	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.
When?	There are no dependencies to perform this test, as this remains to be a preliminary 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 30 minutes. 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 code. First, the code must be compiled; at this stage, any syntax errors can be identified and fixed quickly. Next, the code will be run, and its output will be analysed. To check the code, it will be checked whether it displayed the proper information at the right time. Below is the successfully tested output of the code.

```
➞ Which answer is correct?
A.-----
B.-----
C.-----
D.-----
C
Your answer is wrong

Do you want hints? Y or N
Y
Think about.....
Please try again: A
Correct
Which answer is correct?
A.-----
B.-----
C.-----
D.-----
B
Your answer is wrong

Do you want hints? Y or N
N
Please try again: C
Your mark of quiz is 75.0
```

Once the quiz is completed, another code will be created to collect the data and display it to the user so they can see their class progress.

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.

The first potential client that was consulted by the design team is a current grade 12 chemistry teacher. She focused most of her attention on the chemical reactions and molecular models, rather than the student quizzes and progress. This potential client agreed with the choice of reactions; she states that they are simple enough to follow, yet complex enough that important lessons can be learnt. She also admired the accuracy of the chemical models, stating that most chemistry conventions were followed. With this feedback, the design team can continue pursuing these chemical endeavours, but more consultation is required for the other subsystems' prototypes.

A potential user was also consulted by the design team. This user is a first-year software engineering student. Although they have very little chemistry experience, they are well acquainted with Unity and other programming softwares. This potential user stated that the team's ideas are interesting and attractive, although he questioned the time required. He stated, from his own experience, that projects like this tend to take longer than they appear. The design team will take this under consideration when updating the team schedule and will attempt to best manage its time. Along with this advice was praise for the team's creativity and willingness to seek code from other sources, rather than creating our own.

After consulting one potential client and one potential user, it is clear that the design team is making good progress. Using advice given by both parties, the design team will certainly reconvene and optimize the team schedule, to ensure minimal time gets wasted.