GNG1103

Design Project User Manual

Utilization and Maintenance of the Organic Chemistry Virtual Reality Software

Submitted by:

The VR Virtuosos (F11)

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Abstract

Amid the recent COVID-19 pandemic, the design team was forced to work remotely and without the necessary testing resources. These obstacles significantly hindered the team's ability to finish the final prototype. Despite these unforeseen issues, the design team did manage to complete most of the subsystems in time.

Since the final prototype is incomplete, the client may wish to have a new team take over the project. In this case, detailed descriptions of the product and all its capabilities are a necessity. To help the client save time and money, the design team created this document, containing all the information needed to finish this final product.

The design team provided detailed instructions on how all the subsystems were created and how they function. As well, the design team included many pictures to help thoroughly describe the subsystem and all its capabilities. In this document, the design team outlines the procedures for the following subsystems of the final prototype: the global environment, the macroscopic reaction, the microscopic reaction, and the pre-lab quiz. All the subsystems played a crucial role in the creation of the final product, therefore detailed explanations on their creation are critical.

Also included in this document is a section describing the steps needed to use the product. This section not only outlines the usage of the different subsystems, it also contains critical information on software installation, and health and safety. Although descriptions of these processes may seem tedious, as it will be one of the only resources that students and clients can refer to when there are issues with the final prototype's operation.

Next, the design team outlined the maintenance requirements for the product, along with its lifespan and performance expectations. Since this product is software, there are very few maintenance requirements, as there are no subsystems whose performance depreciates. These factors allow the final product to have a long lifespan with minimal maintenance. Also, in this section, the design team includes some troubleshooting instructions for some common product failures. Despite the lack of thorough testing of the final product, the design team still provided step-by-step technical instructions in case the microscopic reaction or *Unity* interface subsystems fail.

In the next section, recommendations for future work were provided. Suggested avenues for future project work, along with lessons learnt by the design team, were included in this section of the document. In the bibliography, the design team provides internet resources and YouTube videos that were references throughout the design process. A new project team can use these resources if there are any uncertainties in the specific subsystem's creation.

Lastly, the design team thoroughly explains the contents of the project deliverables and the design files containing the final prototype. The project deliverables outline the design team's weekly progress and the stages of the engineering design process. The design files include assets, scripts, motion trackers, and other VR-specific resources that the design team used to create the final product.

Table of Contents

Util	ization a	nd Maintenance of the Organic Chemistry Virtual Reality Softwarei
Abs	stract	ii
Tab	le of Cor	ntentsiv
List	of Figur	resvi
List	of Table	es vii
List	of Acro	nymsviii
1	Introdu	ction1
v	Vhat is th	ne problem and why is it important?
F	undamer	ntal needs of the client and users
v	Vhat diffe	erentiates this product from others?
Ν	Iain func	ctions of the product
2	How th	e Prototype is Made
C	lobal En	vironment
	2.1.1	Equipment List
	2.1.2	Instructions7
N	lacrosco	pic Reaction7
	2.2.1	Equipment List
	2.2.2	Instructions
N	licrosco	pic Reaction9
	2.3.1	Equipment List
	2.3.2	Instructions
		iv

	Pre-Lab Q	uiz10
	2.4.1	Equipment List
	2.4.2	Instructions11
	BOM (Bil	l of Materials) 12
3	How to	Use the Prototype
	Functions	of the Prototype and How it Works14
	How to In	stall the Prototype
	Health and	l Safety Guidelines15
4	How to	Maintain the Prototype16
	Troublesh	ooting with Technical Instructions16
	4.1.1	Microscopic Reaction
	4.1.2	Unity Interface
5	Conclus	sions and Recommendations for Future Work
6	Bibliog	raphy
A	PPENDIX	I: Design Files
7	Project	Deliverables
8	Final Pr	roduct
	Assets	
	Library	
	Project Se	ttings
	Various St	teamVR Files

List of Figures

Figure 1: General Layout of the Laboratory Environment	. 5
Figure 2: The Quiz Room/ Entrance	. 5
Figure 3: The Reaction Room	. 6
Figure 4: The Original Lab Environment from Prototype 2	. 6
Figure 5: Glassware and Solutions Needed to Conduct the Macroscopic Reaction	. 8
Figure 6: The Molecular Models in the Reaction Room	. 9
Figure 7: The Molecular Models in the Reaction Room	. 9
Figure 8: The Pre-Lab Quiz	11

List of Tables

Table 1: Interpreted needs collected during the first client meeting	2
Table 2: Comprehensive Bill of Materials	12
Table 3: List of Project Deliverables	20
Table 4: List of Folders and Subfolders in the Final Product File	22

List of Acronyms

Acronym	Definition
VR	Virtual Reality
DT	Design Team
DC	Design Commons

1 Introduction

This user manual has been divided into several sections for easier access to crucial information concerning the VR system. In this first section, the DT will provide a general overview of the product and some information on the needs that the DT needed to address.

Next, the DT included a section describing how the prototype was made. This section will outline the process that the DT followed to generate the final product. Detailed descriptions of the various subsystems implemented into the final prototype will also be provided.

The DT will also include a section describing the steps needed to use the product. This section is crucial, as it will be one of the only resources that students can refer to when there are uncertainties on the final prototype's operation. Installation instructions for this product, along with health and safety measures, were also added to this section of the document.

Maintenance of the final product will also be included in this document. The information contained in this section is critical in prolonging the prototype's lifespan and optimizing its performance. Troubleshooting instructions for common subsystem failures were also included in this section of the document.

The DT also outlines its recommendations for future work on this product. As the DT was unable to finish the product due to the COVID-19 outbreak, the client may wish to continue working on this product. With the DT's input on the best avenues for future work, the client can save a lot of time and money.

Lastly, all the design files associated with the final prototype are also provided to the client. Detailed descriptions of these design files will also allow the client to efficiently find a critical subfolder for future use.

What is the problem and why is it important?

The client presented the DT with a frequent problem amongst first-year organic chemistry students. Often, students misinterpret the impact that changes on the macroscopic level have on the molecular level and vice versa.

The client presented this relationship using an example with boiling water: when water is heated on the macroscopic level, the molecules at the microscopic level move faster and collide more frequently. Students, most often first years, disregard this relationship as it is difficult to visualize. The DT's task is to help students visualize this relationship and comprehend some common chemistry misconceptions, like reaction rates and molecular rotation.

It is important to solve this problem because it will allow students, at an earlier stage of their education, to learn some of the fundamental relationships in organic chemistry. With the DT's solution, students will have access to a more interactive way of learning new material and conducting experiments.

Fundamental needs of the client and users

The DT had the opportunity to collect the client's and users' needs during the first client meeting. "Raw data" was collected by the team to interpret it into a problem statement. The DT used this statement throughout the design process to remain focused on the client's needs.

The need collection and interpretation stage, also known as the "empathize and define" stage, was conducted for Project Deliverables B and C. Along with collecting and interpreting the client's needs, they were placed into a table and their relative importance was determined. This relative importance allowed the DT to focus on certain needs over others, saving valuable time and effort.

Included in the table below are the most significant client needs. These needs were given the relative importance of 4 or 5, meaning that the DT ought to address them.

Need	Need Description	Importance
1	Students and teachers with minimal virtual reality experience can use the product	5
2	Students can learn organic chemistry effectively with the system	5
3	Through visualization and interaction with the software, the students can better comprehend the topic	5
4	Product uses and displays scientifically accurate material (e.g. reaction rates)	4
5	System immerses students in the reaction, to help them understand all the components of a reaction	4
6	Focuses on speed of reaction and proportionality	4

Table 1: Interpreted needs collected during the first client meeting

Also collected during the first client meeting were some constraints and assumptions. Although these are not considered needs, the DT must still address them. Some of the most significant constraints and assumptions that the DT focused on during the production of the final prototype are the following:

- Cost
- Start up time
- Portability and accessibility
- Assumed that students and teachers have no prior VR experience

By considering all these needs, constraints, and assumptions, the DT effectively addressed most of the client's wishes for the product.

What differentiates this product from others?

All products on the market have competition. Since competitors' products address similar needs, it is crucial to create a superior product. To create a unique product, the DT decided to use VR, which enables users to physically interact with their surroundings. This exceptional difference, along with a significant emphasis on user experience, will play a crucial role in creating a better product.

In this case, the DT focused on authenticity, physical interactivity, and maximizing user experience. The DT decided to address these factors by creating scientifically accurate chemical reactions, a realistic laboratory environment, and interactive quizzes and help menus. As well, the DT allows the user to physically interact with any lab equipment in the environment, whether it is necessary for the experiment or not. This allows the students to control their own actions, rather than following a fixed procedure, like other products. Since the DT effectively addressed all these factors, the final prototype is better than the competition.

Main functions of the product

This final product allows first-year students to physically interact with macroscopic and microscopic reactions using a VR system. With the help of VR headsets and hand controllers, the student can effectively visualize and become immersed in dynamic chemical reactions.

When the users first enter the environment, they can complete the pre-lab quiz. This quiz is designed to determine whether students have effectively prepared for the experiment. Although this quiz is simple, it still successfully confirms the student's prior knowledge of the various components of the chemical reactions. Next, the student conducts the macroscopic reaction. This is the real-world component of the chemical reaction that the user can interact with. To conduct this experiment, the user must successfully pour the correct solutions into the correct glassware to form a precipitate product. Once this experiment has been successfully conducted, the user is prompted to interact with the microscopic reaction.

While in the reaction room, the student can grab, hold, or throw the molecular models. This physical interaction allows students to visualize the physics of a chemical reaction more effectively at the molecular level. Users can interact with reactants, intermediates, or products, thus providing students with a thorough grasp of all the concepts of chemical reactions

With all these functions and features of the final prototype, the first-year student can effectively visualize the connection between the macroscopic and microscopic levels of a chemical reaction.

2 How the Prototype is Made

The DT had six weeks to complete this product. To ensure efficiency, three different prototypes were created, all of which have different purposes, importance, and fidelity. Some of these prototypes, the first and second in this case, were subsystem based, whereas the third prototype focused more on implementing all these subsystems into the final product. This decision allowed the DT to analyse each subsystem independently before it is implemented into the global system, thus optimizing the prototype's performance.

Not only did the DT need to build each subsystem prototype, testing also needed to be conducted. Testing allowed the DT to confirm that each subsystem was functional, accurate, and effectively addressed the client's needs.

The DT's decision to separate the global system into subsystems maximized efficiency when working on this project. This decision allowed the DT to work separately, which minimized stress on the team's project plan. The most significant subsystems, all described in further detail below, are the classroom environment, the macroscopic reaction, the microscopic reaction, the pre-lab quiz, and the help menu. By separating the global system into different subsystems, the design team effectively minimized interdependencies, which in turn maximized efficiency.

Global Environment

The environment for this VR product includes several unique features; there are three different rooms, four usable lab benches, and a lot of interactive chemistry equipment. All these elements were added to the final product to maximize user experience and to make the environment look more authentic. The DT focused on making the VR classroom look realistic by paying attention to lab safety guidelines, and the laboratory layout. Most, if not all, students who will be using this product are familiar with the guidelines and layout and will hopefully appreciate the attention to detail.

The DT also included a student help menu in this subsystem. This menu is designed to guide students throughout their VR experience and outline the general lab procedure. To ensure that the help menu is always visible and available to students, the DT installed it on the blackboard in the laboratory. Although this subsystem is uncomplicated and usually forgotten, it maximizes user experience and makes the lab environment look more authentic.

Below are pictures of the environment from different angles. A picture of the original lab environment from Prototype 2 has also been included



Figure 1: General Layout of the Laboratory Environment

Figure 2: The Quiz Room/ Entrance



Figure 3: The Reaction Room



Figure 4: The Original Lab Environment from Prototype 2



2.1.1 Equipment List

- Chemistry Class Asset
- Chemistry Bundle Asset
- SteamVR Plugin
- HDR Skybox

How the Prototype is Made

2.1.2 Instructions

The classroom environment subsystem used in the final prototype consists of three smaller rooms: the entrance/quiz room, a laboratory, and a reaction room. When creating this subsystem, the rooms were added in stages. In Prototype 1, only the classroom skeleton was created using the Chemistry Class asset, as seen in Figure 4. The additional rooms were still in the brainstorming stages at this point.

Prototype 2 saw the addition of glassware from the Chemistry Bundle asset to the desks, used to create the macroscopic reaction. The laboratory was designed to house this macroscopic reaction. This room was designed to be simple, uncluttered, and visible from all points in the global environment.

The final prototype saw most of the advancement in terms of the overall design of the environment subsystem. Firstly, a help menu to guide students through the experiments was added to the blackboard, as seen in Figure 1. Next, an entrance room was introduced; this room includes a student greeting and the pre-lab quiz, as seen in Figure 2. Finally, the three rooms were joined via hallways. As an added feature, teleportation points were placed around the environment, with the help of a few YouTube videos in the BIBLIOGRAPHY, enabling users to move about more freely.

Macroscopic Reaction

This component of the VR system allows the users to conduct a chemical reaction and analyse the macroscopic process. This perspective of the reaction highlights the "real-world" experiments that the users conduct regularly in chemistry labs. For this experiment, students are tasked with pouring $CaCO_3$ solid, using the VR hand controllers, into an Erlenmeyer flask filled with HCl. When the experiment is conducted, users can observe a precipitate formation and a gas being released from the flask. Although this experiment is quick and simple, it still allows students to observe crucial properties of a common organic chemistry reaction. The DT's goal was not to create an elaborate reaction; the goal was to create a realistic and authentic reaction that students can learn from.

Below is a picture of all the chemistry equipment needed to conduct the macroscopic reaction.



Figure 5: Glassware and Solutions Needed to Conduct the Macroscopic Reaction

2.2.1 Equipment List

- Chemistry Class Asset
- Chemistry Bundle Asset
- SteamVR Plugin
- HDR Skybox

2.2.2 Instructions

The process used to generate the macroscopic reaction was simple. All the steps described below were conducted for the final prototype in just one day. To create this subsystem, first, two different glass containers were placed on a lab bench in the laboratory. One was a 50mL beaker, used to store the CaCO₃ solid, and the other was a 250mL Erlenmeyer flask, used to hold the HCl solution.

Next, solids and solutions were added to their respective glassware with help from the Chemistry Bundle asset. Finally, a "control" was added dictating that when the two reactants mix, a solution would appear in this flask. Just like in ordinary experiments, this final solution bubbles and a white precipitate forms at the bottom of the flask.

In case the student poorly executes the macroscopic reaction, the DT added extra $CaCO_3$ solid and HCl solution on the lab bench, as seen in Figure 5.

Microscopic Reaction

This component of the chemical reaction allows students to physically interact with the molecular models. While in the reaction room, the users can grab, hold, or throw the molecular models. This physical interaction allows students to visualize the physics of a chemical reaction more effectively at the molecular level. Users can interact with reactants, intermediates, or products, thus providing students with a thorough grasp of all the concepts of a chemical reaction. The DT designed this portion of the final product to not have a set procedure because it allows students to interact with the molecules more freely. By maximizing user experience, the DT effectively teaches the relationship between the macroscopic and microscopic levels of a chemical reaction to organic chemistry students.

Below are pictures of the microscopic reaction and the molecular models in the reaction room.

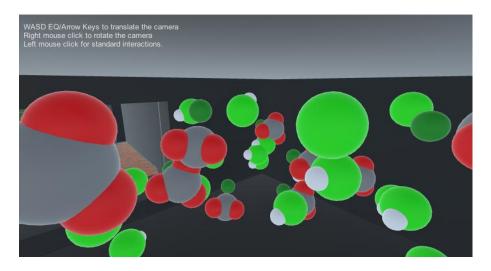
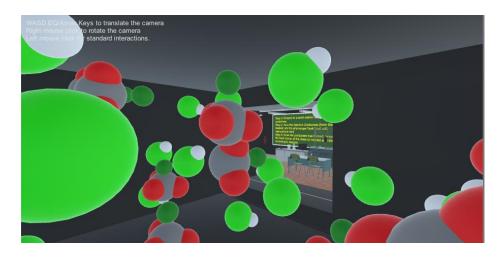


Figure 6: The Molecular Models in the Reaction Room

Figure 7: The Molecular Models in the Reaction Room



2.3.1 Equipment List

- Chemistry Bundle Asset
- SteamVR Plugin
- HDR Skybox

2.3.2 Instructions

The process of creating the microscopic reaction was linear; it consisted of successive improvements and innovations with every prototype that the DT built. For Prototype 1, 3D spheres, with colours corresponding to those of the accepted chemical modelling colours, were created. These spheres were then accurately sized relative to each other and were then saved in a file named for the element they represent. Then, molecules were created by joining these spheres together and locking their relative positions. These molecular models represent the reactants and products of the reaction.

For Prototype 2, the molecules were set on paths of random vector motion within a set region. This movement mirrors the random molecular motion consistent with a closed volume container. The DT's goal for this prototype was to make the microscopic reaction more realistic and authentic.

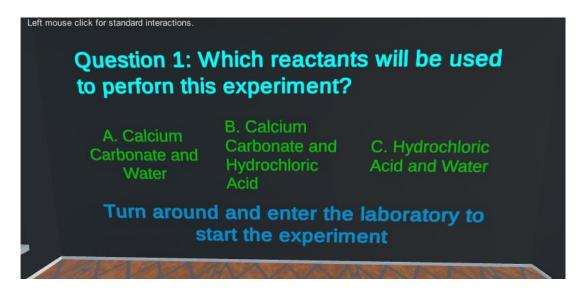
During the creation of the final prototype, first, the ability for molecules to break bonds and bounce around the container was added. Then, the molecules were programmed to re-form bonds to form the molecular products. The DT programmed the breaking and forming of bonds to be random and spontaneous, just like in actual chemical reactions.

Pre-Lab Quiz

When the users first enter the environment, they can complete the pre-lab quiz. This quiz is designed to determine whether students have effectively prepared for the experiment. Although this quiz is simple and short, it still successfully confirms the student's prior knowledge of the various components of the chemical reactions. Although this aspect of the product does not directly affect the student's understanding of macroscopic and microscopic reactions, it is still an important feature, nevertheless. This feature adds another level of physical interaction to the product, thus maximizing user experience and addressing the client's needs.

The COVID-19 outbreak and facility closure restricted the DT from completing this subsystem. As seen in the picture below, text boxes were added in place of the pre-lab quiz to conceptualize the DT's plans. With more time or different circumstances, the DT would have finished and thoroughly tested this subsystem quickly.

Figure 8: The Pre-Lab Quiz



2.4.1 Equipment List

- Quiz Template Asset
- SteamVR Plugin
- HDR Skybox

2.4.2 Instructions

This subsystem was originally designed along with Prototype 1 and was improved upon as the global system progressed during development. The first step to creating the pre-lab quiz was to design a basic quiz outline. A simple quiz format was designed outside of the 3D software, to test its grading structure. A three-question quiz was designed with scores increasing with the number of correct answers and decreasing with the number of used hints. This quiz was translated to a *Unity* format using a quiz template asset.

During Prototype 2 development, the concept of hints was removed from the quiz. Thus, a prototype of this subsystem was created. This layout revealed a question at the top of the screen and three/four multiple-choice options covering the remaining portion. At this point, no content had yet been added to the questions; only "filler" questions and answers were inputted. To add content, first, a quiz length of three questions was decided upon. These questions, as seen below, were then added:

- What are the reactants?
- What are the products?
- What would happen if the reaction were to occur at a higher temperature?

The basic structure of the subsystem had been completed; the only part of the subsystem remaining was for the user to physically interact with the quiz options using hand controls. This feature was unable to be completed due to COVID-19 closing the testing facilities. This subsystem, however, is currently fully completed with the ability to select options using a PC.

BOM (Bill of Materials)

A Bill of Materials table contains all the materials used to generate this product. These materials are called "assets" by *Unity*. The table below includes both purchased and free materials that the DT needed. Some of the assets in the table are tangible, like the chemistry class environment, and some are intangible like the SteamVR plugin. Although some of these materials are more significant than others, they were all crucial in helping the DT create the final product.

The DT was informed at the beginning of this project that there would be a \$100 budget. Although this limited the DT during the ideation stage, once the project work was underway there were several instances where assets were not necessary. Once this project was "completed," it was concluded that the DT adhered to the budget with substantial room to spare.

Item Number	Item Description	Quantity	Unit Price	Total Item Cost
1	Chemistry Class – School	1	\$29.99	\$29.99
	Asset used to create the			
	environment			
https://assetsto	re.unity.com/packages/3d/props/inter	rior/chemistry-	class-school-9	92668
2	Quiz Template	1	\$9.00	\$9.00
	Used to generate the pre-lab quiz			
https://assetsto	re.unity.com/packages/templates/syst	tems/quiz-temp	plate-117119	
3	Chemistry Bundle	1	\$5.00	\$5.00
	Provided the remaining lab			
	equipment (glassware, solutions)			
This item has s	since been removed from the Unity as	sset store		
4	SteamVR Plugin	1	\$0.00	\$0.00
	Made the software VR compatible			
https://assetsto	re.unity.com/packages/tools/integrati	on/steamvr-plu	ugin-32647	
5	Free HDR Sky	1	\$0.00	\$0.00
	Controlled the lighting inside the			
	environment			
https://assetstore.unity.com/packages/2d/textures-materials/sky/free-hdr-sky-61217				
			Total Cost	\$43.99

Table 2: Comprehensive Bill of Materials

The "Chemistry Class – School" asset was purchased by the DT to help create the laboratory environment. Included with this purchase were the room structure, laboratory furniture, a small selection of chemistry glassware, and a wide variety of colours and textures. This asset was more important for the design team as it provided most of the tangible objects in the VR software.

The "Quiz Template" asset was purchased to generate the pre-lab quiz. The DT's original plan was to input the already conceptualized quiz questions and implement this quiz into the global system. Unfortunately, *Unity3D* no longer supports this asset, so the DT was never able to use it. If the DT had more time to work on this project, another product would have been considered instead.

The "Chemistry Bundle" was purchased because it provided the remaining chemistry lab equipment that the DT needed. Some equipment includes 50mL beakers, 250mL Erlenmeyer Flasks, and other equipment that would make the environment more authentic. This purchase was successfully implemented into *Unity*; however, it appears that the product has been removed from the *Unity* asset for an unknown reason.

The "SteamVR plugin" is an example of an intangible purchase. This asset made the software VR compatible with all VR systems. Some sub-assets that this purchase provided include teleportation, a first-person camera, and various audio/visual plugins.

Lastly, the "Free HDR Sky" was purchased to control the lighting around the lab environment. This often-overlooked asset allowed the DT to make the environment look realistic and clear for the users.

3 How to Use the Prototype

Functions of the Prototype and How it Works

This final product allows first-year students to physically interact with macroscopic and microscopic reactions using a VR system. With the help of VR headsets and hand controllers, the student can effectively visualize and become immersed in dynamic chemical reactions.

When the users first enter the environment, they can complete the pre-lab quiz. This quiz is designed to determine whether students have effectively prepared for the experiment. Although this quiz is simple, it still successfully confirms the student's prior knowledge of the various components of the chemical reactions.

Next, the student conducts the macroscopic reaction. This is the real-world component of the chemical reaction that the user can interact with. To conduct this experiment, the user must successfully pour the correct solutions into the correct glassware to form a precipitate product. Once this experiment has been successfully conducted, the user is prompted to interact with the microscopic reaction.

While in the reaction room, the student can grab, hold, or throw the molecular models. This physical interaction allows students to visualize the physics of a chemical reaction more effectively at the molecular level. Users can interact with reactants, intermediates, or products, thus providing students with a thorough grasp of all the concepts of chemical reactions

With all these functions and features of the final prototype, the first-year student can effectively visualize the connection between the macroscopic and microscopic levels of a chemical reaction.

The product functions with a lot of help from *Unity* and *SteamVR*. These programs allow this VR software to function properly and display the correct outputs depending on the situation. The DT manipulated countless assets in *Unity* to create this product, all of which are necessary for the final prototype's optimal performance.

Although the DT did put in countless hours of demanding work into this final prototype. *Unity* and *SteamVR* also provided many resources and references that run in the background. The files containing these resources, all of which ensure the program works, are found in the DESIGN FILES section in this document. These files (scripts, assets, motion trackers, VR-specific, etc.) all work together to make this product function. These coordinated efforts monitor the student and their actions and produce the correct outputs when needed. These efforts ensure that the student can efficiently and effectively learn organic chemistry using VR.

How to Install the Prototype

To "install" this prototype, simply open the project file titled "Final Product" using *Unity*. The link to the file is included in the DESIGN FILES section of this document. Once this document is opened in *Unity*, the files need to be compiled before they can be used. To compile them, the user must press the 'play' button located at the top of the display window. The compiling process may take a few minutes for the first time.

Next, the user must set up the *HTC Vive VR* headset and controllers. A link has been provided in the BIBLIOGRAPHY titled "Unity lab part 2 & 3.pdf" outlining the process.

Once the program has successfully compiled in *Unity* and the *HTC Vive VR* is completely set up, the final prototype is ready for usage.

Health and Safety Guidelines

HTC Vive provides all the safety precautions when using this product. Careful consideration of these guidelines is recommended. The DT will summarize the most significant points below:

- Students/users should not operate the VR system for longer than 30 minutes at a time
- A safe distance must be kept from surroundings whenever the product is in use
- No horseplay when the product and VR equipment are in use
- Students should not operate the system without another person present

More details on health and safety when using this VR system can be found at the link address below:

https://www.tomshardware.com/reviews/htc-vive-virtual-reality-hmd,4519-4.html

4 How to Maintain the Prototype

To determine the final prototype's lifespan and performance, testing must be conducted at every stage of production. Early in the product's development, the DT was constantly testing the product and fixing any issues accordingly. However, amid the recent COVID-19 outbreak, the testing facilities closed, restricting the DT from testing, and analysing the product.

Since the *Design Commons* closed and the testing of the final product was never conducted, the DT is unsure of the prototype lifespan. Despite limited testing, the DT determined that there is no need for regular product maintenance. Since this final prototype is software, parts can not degenerate or lose performance. These positive features help prolong the product's lifespan, addressing the client's need for limited product performance deprecation.

Despite the facility closure and the DT's inability to access VR headsets and controllers, some testing of the final prototype was conducted using a PC. Although the DT was unable to test teleportation and grabbing objects, for example, the DT still managed to ensure the help menu displayed accurate information. Despite the DT's inability to gather detailed data on the prototype's performance with various inputs, valuable information was collected, nevertheless. For example, the DT ensured that the laboratory environment was accurate and authentic, which were significant client needs.

Overall, very little maintenance is needed for this final prototype, as it is software. Since its subsystems do not lose performance, there is no need to replace or update parts of the product. However, if the DT had access to the necessary testing resources, additional issues related to product maintenance may have been discovered.

Troubleshooting with Technical Instructions

The design of this final product is simple and does not have too many areas that can fail. However, the DT will still provide detailed instructions on a few sections that may require troubleshooting. The subsystems that will be troubleshot in this section are the following: microscopic reaction and *Unity* interface. These two components of the final prototype are most likely to fail because they are the most dynamic subsystems that the DT generated.

4.1.1 Microscopic Reaction

If the DT were to put this product on the market, more testing would be conducted, and better troubleshooting instructions can be provided. However, the DT will outline technical instructions of some components that failed during initial subsystem testing.

If the molecules no longer move, collide, or interact with each other.

If this issue occurs, there is a problem with the microscopic reaction's waypoints. This issue affected the DT early in production but has not caused any extreme failures. To fix this issue, the waypoints must be restarted, highlighted in the steps below.

- 1. Disconnect the VR headset and controllers from the laptop/PC containing the VR software
- 2. Close the *Unity* window displaying the final prototype
- 3. Go to the "Final Product" file on the computer
- 4. Refresh the file's contents using the 'refresh' button
- 5. Re-open the software in Unity and reconnect the headset and controllers

The DT did not experience any other issues with this subsystem. More testing may reveal underlying problems, but the belief is that the instructions above should work as well.

4.1.2 Unity Interface

When creating the player and teleportation points in Unity, the DT experienced some technical issues with the Unity software. More testing, however, might reveal some other underlying issues that the DT has not noticed.

If the player teleportation is not functioning properly.

- 1. Recalibrate the VR headset and controllers
 - a. Close the *Unity* application on the laptop/PC
 - b. Close the HTC Vive application
 - c. Re-open the SteamVR application that closes when HTC Vive closes
 - d. Reconnect the headset and controllers
 - e. Re-open the *Unity* application
 - f. If the issue persists, consult the steps below
- 2. Go to the "Final Product" file on the computer
- 3. Refresh the file's contents using the 'refresh' button
- 4. Re-open the software in Unity and reconnect the headset and controllers

Any issues from this subsystem of the final prototype were fixed with the steps above. With more research and testing, the DT may discover more efficient troubling shooting methods.

5 Conclusions and Recommendations for Future Work

In this section, the DT will summarize the project and the most significant details of the final prototype. As well, lessons learnt from working on this project will also be provided. This information offers some insight on the DT's efforts and the obstacles that future teams may encounter. Lastly, the DT will suggest the most productive avenues for future work to save the client time and money.

For this project, the DT built a VR system that teaches organic chemistry to first-year students. The goal of this system was to help students visualize the connection between the macroscopic and microscopic levels of a chemical reaction. The DT needed to consider several constraints and assumptions when designing this product. Some of the issues that needed to be addressed include the following: the product had to be easy-to-use, inexpensive, and physically interactive.

To effectively demonstrate the relationship between macroscopic and microscopic, the user can physically interact with both reactions. The students can conduct an experiment and observe products by performing a Hydrochloric Acid and Calcium Carbonate reaction. As well, the students can grab and throw the molecular models from the microscopic level, thus providing a new perspective of the chemical reaction.

When working on such a large product with so many dynamic components, there will always be areas of struggle. While working on this product, the DT faced a COVID-19 pandemic and countless technological issues. Although these obstacles caused immense frustration at times, the DT still learned valuable lessons from this experience.

Firstly, conducting extensive research and gathering information from comparable products conserves a lot of time when creating a new product. With the help of these resources, the DT managed to save a lot of money and effort when creating the final prototype. As well, careful consideration of personal and team time management is crucial. This, along with meticulous organization and communication, allowed the DT to minimize wasted time and effort.

Since the DT was unable to fully complete and test the final prototype, the client may wish to continue this project with another team. In this case, the DT has a responsibility to provide advice for future work to save the client time and effort.

Firstly, testing the product in its current state must be the priority. The results of this testing will inform the client of the work that has been completed and which tasks remain. Next, researching new methods for the pre-lab quiz and help menu must be conducted. This research will allow a new team to finish these crucial subsystems. Lastly, creating a game-like software would be a good addition to the product. This addition can make the VR system more enjoyable and attractive to first-year students.

6 Bibliography

Included in this section are some YouTube videos and internet resources that the DT used throughout this project.

For general information on *Unity3D* and testing with the *HTC Vive* set:



Player Creation and Teleportation: https://youtu.be/iJ0oNYIUFJo

Building 3D Structures in Unity: https://youtu.be/ebJ0TY2KKog

Creation and Implementation of the Particle System: https://youtu.be/oPUxv-zClNA

Usage of Materials and Textures: https://youtu.be/IFlXvDZezBQ

APPENDIX I: Design Files

7 Project Deliverables

In the file submission on MakerRepo, the DT included all the project deliverables. The client can access these files and analyse the DT's weekly progress through the engineering design process. The link included below provides access to the file submission on MakerRepo.

https://makerepo.com/PeterVanikiotis/gng1103f-f11-organic-chemistry-vr-project

Below is a table containing all the project deliverables included in the MakerRepo submission. As well, a brief description of the deliverable and the design stage in general will be provided.

Name of Project Deliverable	Brief Description of the Deliverable
Need Identification and Problem Statement	 The DT collected the client's needs These needs were then interpreted and ranked by importance These needs were used to create the problem statement This statement was used throughout the design process to keep the DT focused on the client's needs
Design Criteria and Target Specifications	 The needs from the previous deliverable were turned into design criteria These criteria allowed the team to benchmark other products This permitted the design team to analyse the competition The data from this analysis helped the team create a better product, with the help of target specifications
Conceptual Design	 This was the brainstorming and ideation process The team came up with global and subsystem concepts These concepts were invented, improved, or completely removed throughout the design process
Project Schedule and Cost	 This update is purely for the client This progress report updates the client on the team's efforts An updated project schedule and cost statement were produced for this deliverable

Table 3: List of Project Deliverables

Prototype I	 This prototype was analytically focused Only theoretical subsystems were created As well, research and testing were the main focuses Very few subsystems were created, a continuation of the brainstorming process with more testing
Prototype II	 This prototype was physically focused More tangible subsystems were created More testing was conducted to provide insight on the prototype's performance Considerable progress, most of the subsystems were completed and tested
Final Prototype Update	 This prototype was physically comprehensive The subsystems were joined to form the global system Due to COVID-19, the team could not conduct the required testing on the global system Completed all subsystem that did not require VR headsets or hand controllers Provided an update on the "next steps" and the team's final thoughts on the product

With the information contained in these deliverables, the client can revisit the DT's progress and attempt to mirror it. In the case that the client wishes to continue this project with a new team, analysis into these deliverables can provide insight into the DT's triumphs and flaws. This information can save the client a lot of time, money, and effort if they choose to continue working on this product.

8 Final Product

If the client wishes to have access to the final product and all its design files, they can email any members of the DT. The immense size prohibits the DT from publishing the file on MakerRepo with the project deliverables. Details of the design files contents will be provided in this section, to help the client decipher through its contents.

Below is a table containing all the folders and subfolders in the "Final Product" file. Also included in this table is a brief list of the contents of each folder and subfolder. It must be noted as well that all the folders and subfolders contained in this file can also be found in *Unity*.

Table 4: List of Folders	and Subfolders in the	e Final Product File
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Name of Folder/Subfolder	Brief List of Contents
Assets	 All furniture and glassware included in the final product Variety of colours and textures Collection of scripts that were used throughout the project Various SteamVR plugins, scripts, and prefabricated objects Collection of "waypoints" controlling the microscopic reaction
Library	• Collection of scripts and various other files with mostly unknown purpose and function
Project Settings	• Collection of assets with unknown purpose and function
Various SteamVR Files	• Collection of .csproj files with unknown purpose and function

Assets

This folder contains all the Unity assets that the design team purchased. All the assets in this folder can be edited, manipulated, and added to the global system.

The most significant contents of this folder are the chemistry lab structure, the laboratory equipment, the "waypoints" controlling the microscopic reaction, ad the colours and textures used throughout the final product.

The DT also moved all the scripts used in the final product into the 'assets' folder for more accessibility. These scripts have a variety of functions, for example, moving the camera, or dictating when a reaction begins.

Also included in this folder are crucial scripts that were included with the SteamVR Plugin purchase; without these scripts, the final product would not function properly.

Library

When creating this final product, it was found that *Unity* and SteamVR implemented many scripts unknown to the DT. Most of the scripts' purpose and functions are unknown but are assumed to be significant. It is recommended by the DT that these scripts not be moved, manipulated, or deleted.

Project Settings

Once again, Unity and SteamVR created and implemented assets into the final product with purposes and functions unknown to the DT. Although the significance of the assets is unknown, it is still recommended by the DT that these scripts not be moved, manipulated, or deleted.

Various SteamVR Files

SteamVR implemented .csproj files into the final product with purposes and functions unknown to the DT. Once again, it is recommended that these scripts not be moved, manipulated, or deleted.