ASHESI

ASHESI UNIVERSITY COLLEGE

IMPROVING THE INTERACTIVITY OF CHEMISTRY IN JUNIOR AND SENIOR SECONDARY SCHOOLS IN GHANA THROUGH VIRTUAL REALITY

UNDERGRADUATE APPLIED PROJECT

B.Sc. Computer Science

Samuel Akwasi Agyemang

2016

ASHESI UNIVERSITY COLLEGE

IMPROVING THE INTERACTIVITY OF CHEMISTRY IN JUNIOR AND SENIOR SECONDARY SCHOOLS IN GHANA THROUGH VIRTUAL REALITY

UNDERGRADUATE APPLIED PROJECT

Applied Project submitted to the Department of Computer Science, Ashesi University College in partial fulfilment of the requirements for the award of Bachelor of Science degree in Computer Science

Samuel Akwasi Agyemang

April 2016

Declaration

I hereby declare that this applied project is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ………………………………………………………………….

Candidate's Name: …………………………………………………………………………

Date: ……………………………………………………………………………………………

I hereby declare that preparation and presentation of this applied project were supervised in accordance with the guidelines on supervision of applied projects laid down by Ashesi University College.

Supervisor's Signature: …………………………………………………………………..

Supervisor's Name: ……………………………………………………………………….

Date: ……………………………………………………………………………………………

Acknowledgement

I would like to express my gratitude to God and my parents for their support throughout this project. I would like to thank my supervisor Mr. Kwadwo Gyamfi Osafo Maafo, for his guidance during this project and Kojo Bosomtwe for encouraging me to undertake this project.

Abstract

Virtual Reality has been around since the 1960's but it was a very expensive technology until Oculus and Google released the Oculus Rift and the Google Cardboard VR headset in 2015 respectively. These releases have made virtual reality more affordable and there has been an increase in apps and materials to develop content. The Virtual Chemistry Lab is a mobile application in VR that aims to allow to students simulate experiments in a virtual lab via the Google Cardboard.

The focus of the project is to improve the interactivity of chemistry in Senior Secondary Schools in Ghana. The current Integrated Science and Elective Chemistry syllabus assigns a lot of time on practical sessions. However, this has not been the case in some Ghanaian schools due to many challenges such as the lack of infrastructure and resources in many rural parts of Ghana.

This paper outlines the various tools and processes used in building and testing the Virtual Chemistry Lab. It also outlines the challenges encountered during the development of the application and how they were solved to achieve the desired outcomes. It will discuss the feedback received from the users who were interviewed and tested the application.

Finally, this paper will evaluates the application and discuss the future of virtual reality in education in Ghana.

Table of Contents

List of Figures

Chapter 1: Introduction

1.1 Introduction and Background

This project is aimed at developing a virtual reality application that runs on Android for students studying Integrated Science Chemistry or elective Chemistry in Senior High School. It will allow students interact with objects in a virtual chemistry lab in order to simulate simple experiments with the help of the Google Cardboard. This application will give students the opportunity to try out virtual experiments on their own without supervision from teachers or the need for physical equipment and chemicals. It will also give them a space to conduct experiments without the risks and dangers of the actual experiments. Students will also be able to repeat the experiments at will while incurring no cost for refilling chemicals or fixing damaged equipment used. The application will also quiz users during these simulations to make sure they understand concepts taught in class and will generate summaries for later revision by the students.

1.2 Problem Statement

"*Science consists simply of the formulation and testing of hypotheses based on observational evidence; experiments are important where applicable, but their function is merely to simplify observation by imposing controlled conditions*." (*Dott and Batten, 2009)* It is impossible to get a clear understanding of scientific knowledge without experimentation. Based on the quote above, Robert H. Dott and Roger L. Batten claim that experimentation is important because it simplifies observations and hence proves or disproves hypothesis, superstitions or claims made by people.

In Ghana, the current integrated science and elective Chemistry WASSCE syllabus, used in most secondary schools, have room for practical sessions. These sessions aim to provide students' understanding with a hands-on experience from topics and concepts taught in class. Currently, the outline for teaching, learning and testing students in Integrated Science in secondary schools and their respective weights are as follows; *"20% for Remembering and Understanding, 40% for Applying knowledge and %40 for Practical and Experimental Skills."*. *(WAEC, 2010)*. The main purpose of the Experimental and Process Skills is to help students plan and design experiments, carry out field and case studies in order observe, compare and identify reasons why certain phenomena occur, after which they can develop practical solutions.

However, this has not been the case in most secondary schools in certain parts of Ghana. Some schools do not have the infrastructure and resources to support students to carry out the experiments or carry them out efficiently. For example, an article by Paul Kabah states that 32 school buildings in the Bunkpurugu/Yunyoo District where destroyed by rainstorms. This affected normal school activities and students where forced sit in these destroyed buildings for class. In addition, some schools such as the Salimboku JHS is overpopulated with an average of 120 students per class compared to the average student per teacher ratio in Ghana, which is 35 students to a teacher per class. It will be challenging for a single teacher to give equal amount of attention or supervision to each student during practical sessions. Another problem facing some Ghanaian schools is the short supply of textbooks for students. It difficult to access the standard WASSCE textbooks to teach students in some districts in Ghana. The conditions mentioned above make it difficult for students to have a meaningful understanding of chemistry since it prevent them from fully taking part in experimentation which is a necessary component in the study of Chemistry and science as a whole.

1.3 Proposed Solution

The Virtual Chemistry Lab is aims at increasing students' interest and understanding in science (chemistry, biology and physics) by allowing them simulate experiments in a virtual world. This project will focus mainly on a virtual Chemistry Lab where students would have the chance to select from 3 different experiments. The main experiments going to be simulated in the application are Dilution, Preparation of Ammonia and the Test for Gases. Students will be guided through the experiment in 3D space from the beginning to the end of each experiment. After the experiment, the summary notes will be generated for students for revision. Later versions of the application will incorporate simulations for both biology and physics.

1.4 Related Works and Literature

Many institutions have come up with ways to make the study of science and science-related studies much more interactive through the use of Immersive Virtual Environments (IVEs) and Augmented Reality but the main focus will be on Immersive Virtual Environments (IVEs). An IVE "*is one that perceptually surrounds the user, increasing his or her sense of presence or actually being within it.*" (*Bailenson*, et al., 2008). IVEs allow the user/players actions and movement to be tracked by using a use of a head-mounted display (HMD) hence giving the impression of being physically present in a 3-D space. IVE can be combined with sound and haptic devices (used to simulate touch) to give a more realistic virtual experience.

Labster also provides educative virtual reality experiment online for university such as MIT, Harvard University and Stanford University. The CSI lab from Labster explores the principles of Polymerase Chain Reaction and Gel Electrophoresis by taking students through an investigation of a murder mystery. At the end of this lab, students learn about the function of DNA polymerase in DNA replication and synthesis and learn about the Polymerase Chain Reaction (PCR) technique using virtual DNA from a blood sample in the simulation.

Molecular Rift is a virtual reality tool for drug designers. It allows users to "*create enhanced 3D environments that simulate physical presence in the real world-a virtual reality.*" (*Norbyy et al, 2015*). Molecular Rift allows users to interact with the virtual world through hand movements and the Oculus Rift, a VR headset. It is able to detect hand gestures via the Microsoft Kinect Sensor and is integrated with the Open Babel toolkit so that users are able to perform cheminformatics functions without the need for input devices. Molecular Rift is open source and is accessible from GitHub.

In addition, Alchemy Learning, together with the International Neuroscience Network Foundation piloted the new virtual reality experience with 8th graders of Hampstead Hill Academy studying science. "*Even in just one 60-minute session it was clear to me that all students were able to quickly adapt to and understand virtual reality as a tool to enhance their learning.*" This was the comment made by Matt Cobb a science teacher at the Hampstead Hill Academy after the test. Alchemy VR is a product of Alchemy Learning, and provides teachers and schools with virtual reality hardware that can be configured and integrated into classrooms. It aims to help students find a more engaging way of learning and also to facilitate teaching.

Duke University's DIVE (Duke Immersive Virtual Environment) is incorporated with its Civil Engineering Curriculum where students interact as employees in a virtual company and work together on the design of 50,000 square feet of campus research space. Students are responsible for the designing of the building and are expected to work together in teams to find the most cost effective, code and standards for the design. Documentations and reports are provided after the course, which could be used in real life to sell the idea of the final design in the IVE.

Another interesting topic about IVEs is that it is being used not just by scientists or science lecturers but also by social scientists as a way of predicting behaviours in human beings based on the decisions they take in the virtual world. This is possible because all actions made by someone using an IVE can be recorded and examined overtime.

Virtual Reality has been around since the 1960's but was not as popular as it is now. Using virtual reality in the classroom was not feasible because it was very expensive and was typically used in aviation to train novice pilots. The development of the Oculus Rift and other virtual reality headsets such as the Cardboard released by Google has made virtual reality more affordable. The Google Cardboard can now be bought online at $14.95. Developers can now identify problems and integrate it into subject areas that can enhance student-learning experiences, in relation to chemistry. However, not everyone owns a VR headset yet so most existing solutions are web applications that run on computers or mobile phones connected to the internet such as Online Chemistry Laboratories by OnlineChemLabs. This web application allows students to perform over 25 virtual experiments online. It also allows students to submit the results of their experiments through the internet to their lecturers so it can be graded. Other solutions are Android applications that can be downloaded from the Play Store. Examples include Complete Chemistry, Chemistry Lab, Organic Chemistry and many others.

1.5 Motivation

Improving the interactivity of science in Ghanaian schools is very important because it is one of the main building blocks to creative thinking and problem solving. "*Science is a way of life. Science is a perspective. Science is the process that takes us from confusion to understanding in a manner that's precise, predictive and reliable - a transformation, for those lucky enough to experience it, that is empowering and emotional*." (*Brian Greene*). Science not only helps us understand ourselves but also the world around us. This understanding brings about innovation that leads to inventions and solutions to solve the problems of the society and the world at large.

The project also aims at minimizing reducing the number of students who fail integrated science after writing their WASSCE examination. For example, 23.63% obtained A1-C6 while 39.19% got D7-E8 and 37.17% had F9 last year. Students who fail this subject find it difficult to get into the university because it is a core subject. This means students have to wait at least 3 months before they retake the subject through the NOV/DEC examination. This is unfair because the chances of passing the course would have been higher if there was a better understanding of the concepts taught in class.

Finally, quality education is a fundamental human right. According to the Article 26 of the Universal Declaration of Human Rights, everyone has the right to be educated. In addition, Section 2 of the Education Act of 1961 states that "*Every child who has attained the school-going age as determined by the Minister shall attend a course of instruction as laid down by the Minister in a school recognised for the purpose by the Minister*".

1.6 Objectives

This section focuses on the main objectives of creating the virtual lab. The main objectives of this project is to create a cheaper replica of physical labs while improving the understanding of students in relation to chemistry. It also talks about the goals of the project aims in developing the Virtual Chemistry Lab. It will also briefly introduce the tools used in the development of the application. The application will feature 3 experiments namely Dilution, Preparation of Ammonia and Test for Gases.

1.6.1 Installing Unity 5.1

Unity is an open source game engine that would be used throughout the development of the application. Unity allows the importation of 3D models, diffuse and normal textures which are necessary for creating materials and also gives users the opportunity to write their own shaders using HLSL. "*A shader is simply a program that runs in the graphics pipeline and tells the computer how to render each pixel.*" (*Omar Shehata, 2015*). Unity also allows rigging of objects and creation animations, which can be used later on in the development of the application.

1.6.2 Importing the CardBoardSDKforUnity Package into Unity

A unity package that provides assets to build a virtual reality application on Android and the iOS.

1.6.3 Modelling the Virtual World

The virtual world of the application would be modelled from scratch using the open source 3D suite Blender 2.76. Blender allows 3D models to be imported in many forms including in the Wavefront file type (.obj) and the Filmbox file type (.fbx) which are both supported in Unity.

1.6.4 Creating textures and UV Unwrapping 3D models

The 3D models created would be unwrapped using Blender's UV unwrapping tool before imported into Unity. UV unwrapping is a technique that allows a 2D image texture to be projected onto a 3D mesh. Photoshop CC would mainly be used to resize and edit textures for the 3D models. Gimp would be used to create tileable textures (seamless textures) and

ShaderMap would be used to generate normal, specular and ambient occlusion maps that would help fake depth and reflection respectively throughout the application. This is done to help create realistic looking scenes because low poly 3D models are going to be used. It also improves the performance of the application by reducing GPU rendering times.

Chapter 2: Requirements

This chapter provides a detailed description of the Virtual Chemistry Lab. It will explain the features of the system, the interfaces of the system, what the system will do and the constraints under which it must operate. This document is intended for both stakeholders and developers of the system. The requirement where mostly gathered through interviews, exiting applications and API from technologies going to be implemented.

2.1 Scope of the Project

This software is an Android application in virtual reality for students studying Integrated Science Chemistry or Chemistry in secondary school. It allows users interact with objects in a virtual chemistry lab to perform simple experiments with the help of the Google Cardboard. This application will feature 3 main experiment which include Dilution, Preparation of Ammonia and Test for Gases. It gives student the chance to simulate these virtual experiments without the risks and dangers of performing the actual experiments. The application quizzes users during virtual experiments to make sure they understand what they do during experiments and generates summaries for students to help them revise what they learnt.

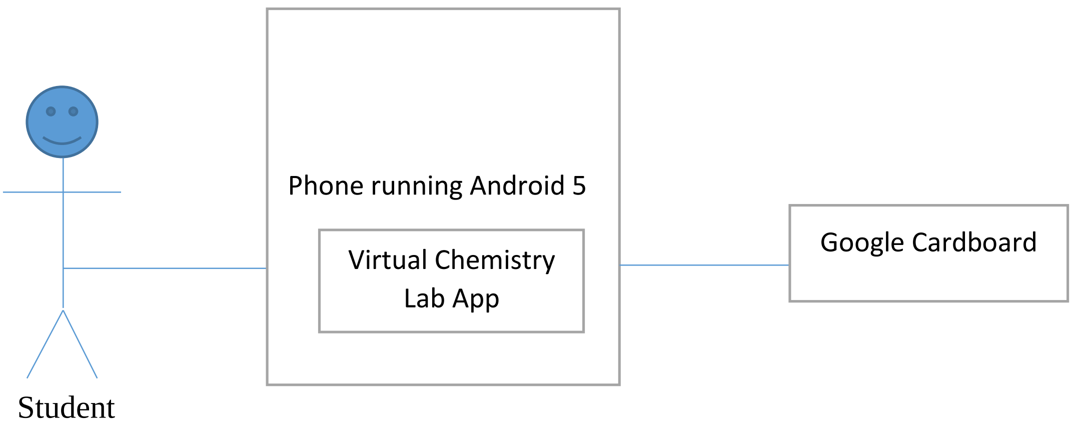

Fig 2.0 – System Environment

The Virtual Chemistry Lab has one main actor, which is the student who is able to interact the virtual world through the Google Cardboard.

2.2 Requirement Gathering

Resources	Information to be gathered	Methodology
Students that have studied and written the WASSCE integrated science chemistry or Chemistry exam.	User specifications.	Information will usually be gathered by one on one interviews with clients.
Similar applications	a. Existing methods of implementation and deficiencies of the program. b. Features people like about the programs.	a. Running and testing similar programs. b. Checking forums and bug reports of people who have used the program before.
Documentation of Unity	a. Information on optimization and efficient runtime methods. b. Important packages and classes that would be needed. c. Memory management d. General information and features of unity.	Reading Unity's Manual and Scripting API.
Blender wiki	a. Information on tools and efficient ways of modelling low poly models.	Reading Blender Wiki.

	b. Efficient way of texturing low poly models using texture atlases.	

Table 2.0- Requirements Gathering

2.3 Functional Requirements Specification

This section outlines the use cases for the student who is the main actor in this system.

2.3.1. Student Use Cases

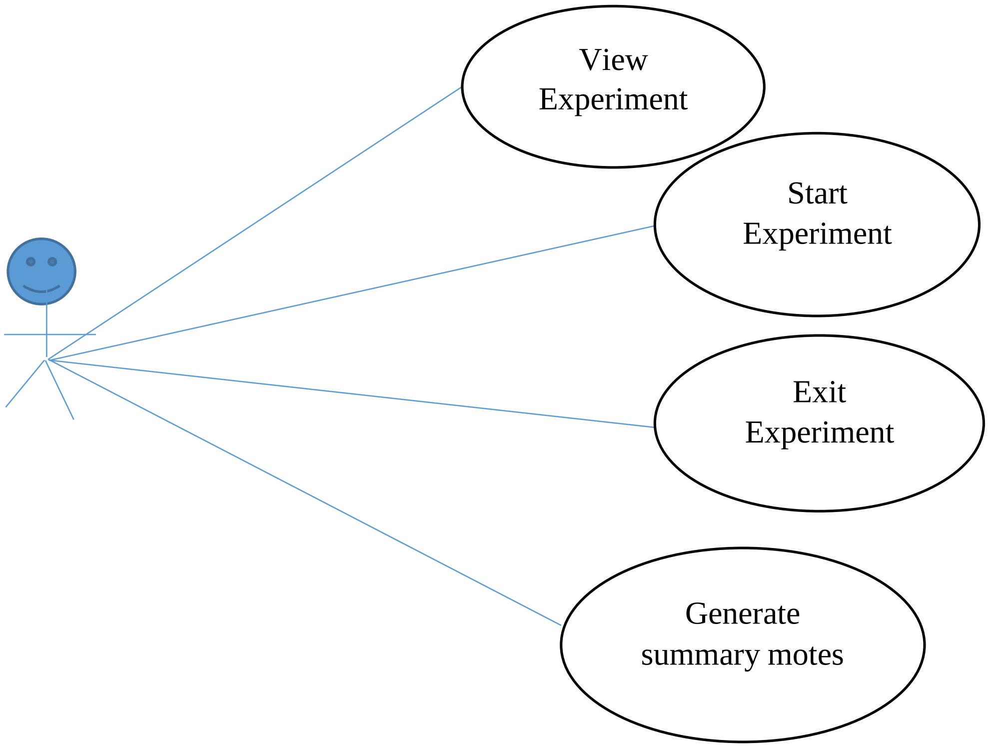

Fig 2.1 System Use Case Diagram

2.3.1.1 Use Case: View Available Experiments

Diagram:

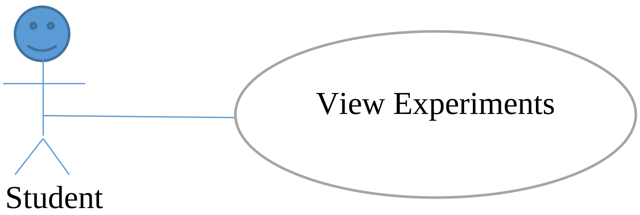

Fig 2.2 Use case diagram: View Available Experiment

Brief Description

The student is able to view the list of available experiments and make a selection.

Initial Step-By-Step Description

1. The student focuses on the Start Experience button in the main menu and pulls the Cardboard trigger.

2. The application shows the student a variety of experiments he can simulate in the selection scene.

2.3.1.2 Use Case: Start Experiment

Diagram:

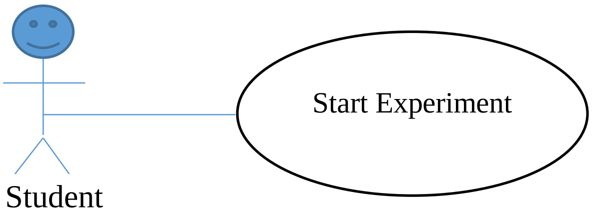

Fig 2.3 Use case diagram: Start Experiment

Brief Description

The student is able to simulate an experiment of choice.

Initial Step-By-Step Description

1. The student focuses on Start Experience button in the main menu and pulls the Cardboard trigger.

2. The application shows the student a variety of experiments that can be simulated in the selection scene.

3. The student focuses on the experiment of choice and pulls the Cardboard trigger to start the experiment.

2.3.1.3 Use Case: Exit Experiment

Diagram:

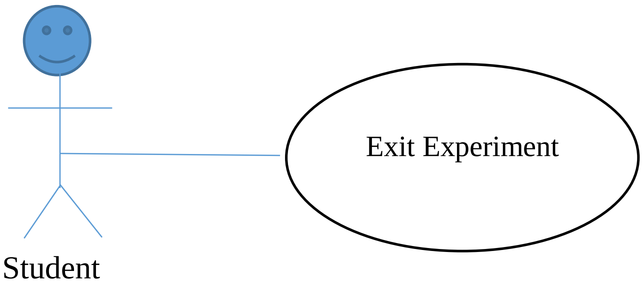

Fig 2.4 Use case diagram: Exit Experiment

<u>Brief Description</u>

The student is able to exit a simulation of an experiment.

<u>Initial Step-By-Step Description</u>

1. The student focuses on the pause button and pull the Cardboard trigger. The pause button can be found in some simulation menus.

2. The application exits the current simulation and switches to the main menu.

2.3.1.4 Use Case: <u>Generate Summaries</u>

Diagram:

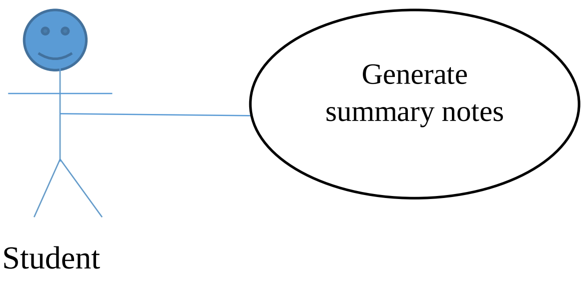

Fig 2.5 Use case diagram: Generate summary

<u>Brief Description</u>

The student generates summaries on the experiment simulated for revision.

<u>Initial Step-By-Step Description</u>

1. The student focuses on the Start Experience button in the main menu and pulls the Cardboard trigger.

2. The application shows the student a variety of experiments he can simulate in the selection scene.

3. The student generates summaries on the experiment about to be simulated by clicking on any simulation of choice.

2.3.2 User Characteristics

The student must have a Google Cardboard or a Google approved Cardboard headset in order to interact with the virtual world. The student is also expect to have a phone which is compatible with the Google Cardboard that runs Android 5(API level 21) or higher. Applications associated with Virtual Reality have been known to cause dizziness, an impaired sense of motion and balance and epileptic seizures. Students with epilepsy must consult a medical practitioner before using the application. It also not advisable for students "*who need sleep, are under the influence of alcohol or drugs, hung-over, have digestive problems, are under emotional stress or anxiety, or when suffering from cold, flu, headaches, migraines, or earaches, as this can increase susceptibility to adverse symptoms*". *(Gear VR Warnings, 2015).*

2.4 Functional Requirements

This is a tabular representation of the functional requirements of the Virtual Chemistry Lab.

2.4.1 View Experiments

Use Case Name	View Experiments
Actor	Student
Trigger	The student must click on the Start Experience button in the main menu.
Precondition	The student must be at the main menu of the application.
Procedure	1. The student focuses on the Start Experience button in the main menu and pulls the Cardboard trigger. 2. The application shows the student a variety of experiments he can simulate in the selection scene.

Basic Path	The student focuses on Start Experience button in the main menu and pulls the Cardboard trigger. 2. The application shows the student a variety of experiments he can simulate in the selection scene.
Post condition	A list of available experiments is displayed.

Table 2- View Experiments Functionality

2.4.2 Start Experiment

Use Case Name	Start Experiment
Actor	Actor
Trigger	The student selects an experiment of choice by pilling the Cardboard trigger.
Precondition	The student must be in the selection scene in order to see the list of experiments
Basic Path	1. The student focuses on Start Experience button in the main menu and pulls the Cardboard trigger. 2. The application shows the student a variety of experiments he can simulate in the selection scene. 3. The student focuses on the experiment of choice and pulls the Cardboard trigger to start the experiment.
Post condition	The simulation of the experiments begins

Table 3- Start Experiments Functionality

2.4.3 Exit Experiment

Use Case Name	Exit Experiment
Actor	Student
Trigger	The student clicks on the close button
Precondition	The student clicks on the pause button, which can be found in some simulation menus.
Basic Path	1. The student focuses on the pause button and pull the Cardboard trigger. The pause button can be found in some simulation menu. 2. The application exits the current simulation and switches to the main menu.
Post condition	The experiment is exited and the application switches to the selection scene

Table 4- Exit Experiments Functionality

2.4.4 Generate Summaries

Use Case Name	Generate Summaries
Actor	Student

Trigger	The student click on a button with the name of the experiment of choice.
Precondition	The student must be in the selection scene in order to see the list of experiments available.
Basic Path	1. The student focuses on Start Experience button in the main menu and pulls the Cardboard trigger. 2. The application shows the student a variety of experiments he can simulate in the selection scene. 3. The student focuses on the experiment of choice and pulls the Cardboard trigger to start the experiment.
Post Condition	Summaries on that particular simulation is generated and written to the student's phone.

Table 5- Generate Summaries Functionality

2.5 Non-Functional Requirements

2.5.1 Performance Requirements

The application should be able to run seamlessly with the user's phone. User should not experience any breakage or lagging that would affect user experience. Low polygon 3D models and low-resolution textures will be used to create the lab environment in order to reduce GPU processing time and ensure efficient memory management.

2.5.2 Security Requirements

The Virtual Chemistry Lab should alert users before installation that personal information could be accessed when necessary and data can be written to the device.

2.5.3 Compatibility Requirements

In the meantime, the application will run on any phone with Android 5(API level 21) installed. The Google Cardboard will also be needed in order interact with the virtual world.

3.0 Design and Implementation Constraints

There are quite a number of constraints associated with the system. The student's phone should be compatible with the Google Cardboard. This compatibility is important because it allows "*fluid head tracking, detecting user inputs such as the trigger, automatic stereo configuration for a specific Cardboard model, distortion correction for Cardboard lenses and automatic gyro drift correction.*"*(Google Cardboard SDK, 2015)* There are also limited input options available to the user. (Only trigger input and timers are available). The designing the user interface of the application is going to be very challenging because it has to be intuitive to users. In virtual reality applications, menus appear in the world space.

Chapter 3: Architecture and Design

This chapter will focus on the abstract models of the Virtual Chemistry Lab. It will also focus and the interaction, interface and structural models of the system components.

3.1 System Architecture

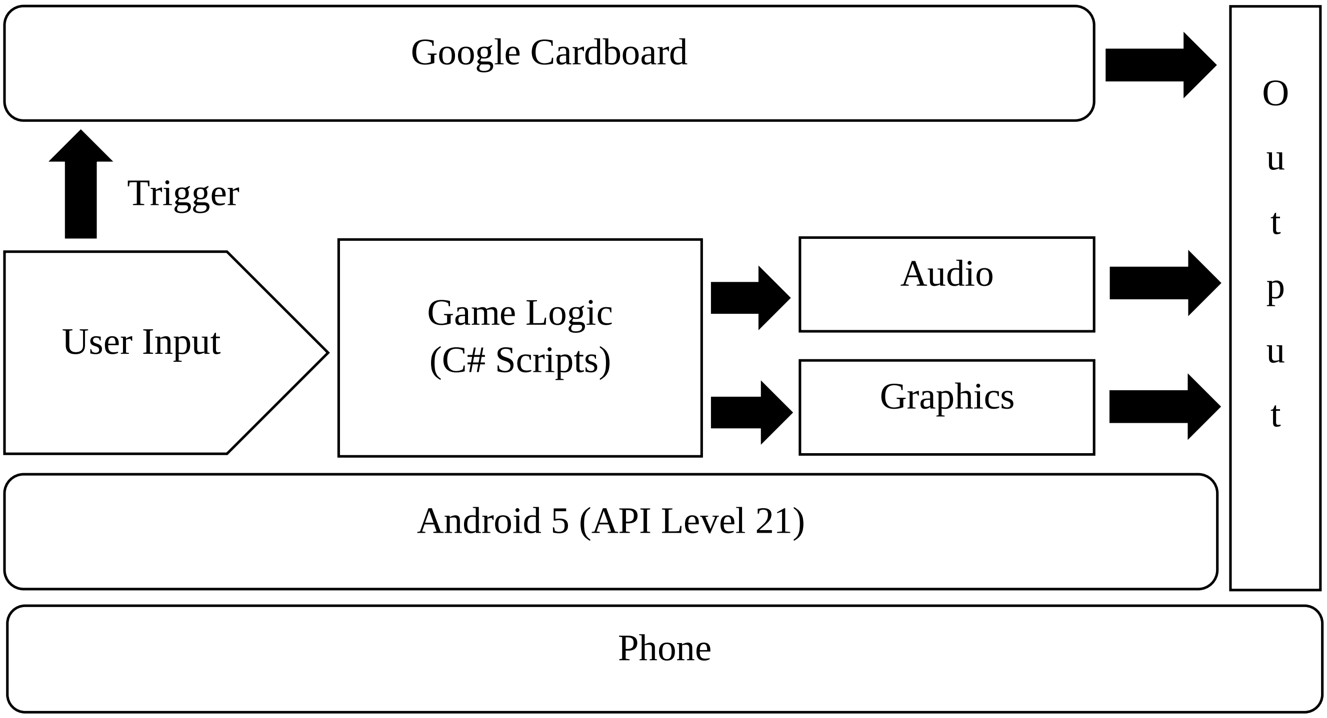

Fig 3.0 System Architecture of the Virtual Chemistry Lab

3.2 Design Patterns

The virtual Chemistry Lab is based on Entity-Component design pattern. Entities are the Game Objects in the scenes and the Components are the characteristics of an entity and "*handles a specific, limited aspect of any entity's appearance or behavior*."(*GameplayKit Programming Guide, 2016)*. Components can be reused with many entities because they are not related to a specific entity.

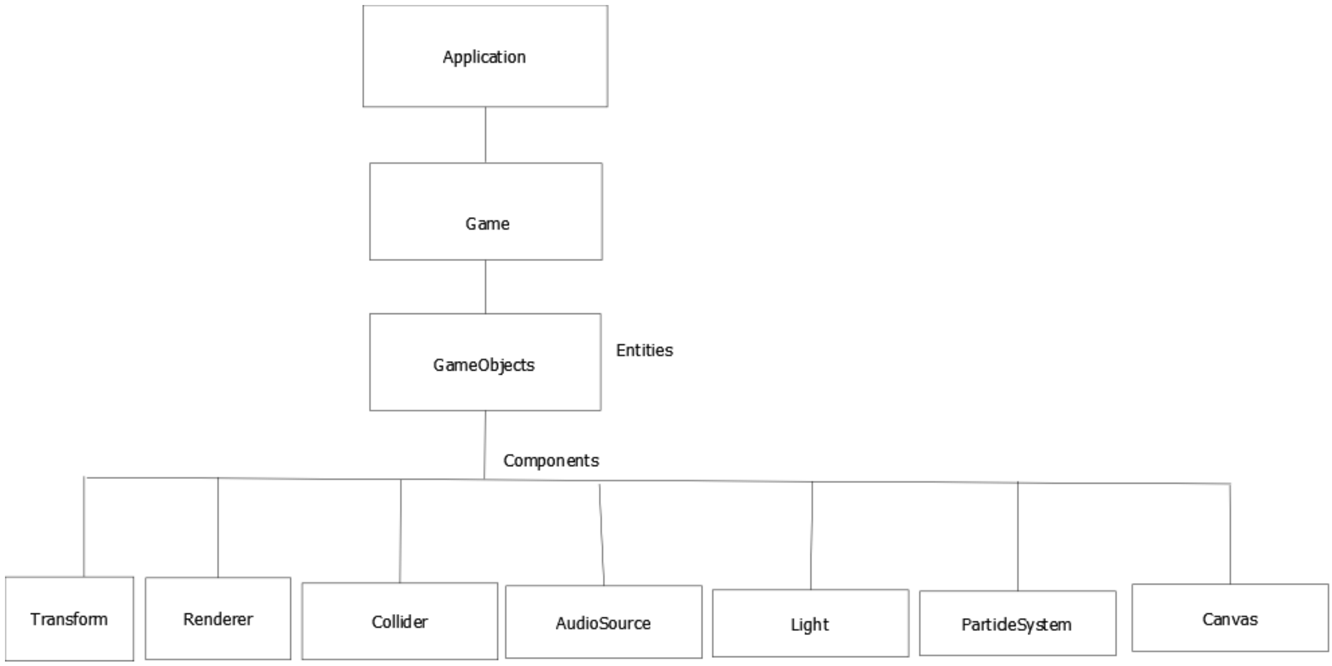

Fig 3.1 Entity-Component Diagram of the Virtual Chemistry Lab

Chapter 4: Implementation

This chapter focuses on the tools and packages used in the implementation of the Virtual Chemistry Lab. The chapter also provides screenshots of the various interfaces of the application in different states.

4.1 Process Model

The application will be developed using the agile software development model. People react to virtual reality applications in different ways so the application will be developed in modules (one experiment at a time), tested by users for feedback before moving on to the next module. The iterative nature of agile development makes it easier for changes to be made to a module to suit the requirements of the users. It also provides quick feedback from users compared to the waterfall model.

4.3 User Interface Design

Designing the user interface of the application was a bit challenging because it had to be very intuitive especially users who had never had an experience with virtual reality. The first challenge was deciding where the in-game menu would appear because unlike non-VR games, the in-game menu appears in the world space. This means users would have to look for the in-game menu in the virtual world before they can access it. The next challenge was the type of affordance to use so users could easily identify different buttons and their uses. In order to solve this problem, a blackboard in the lab was used to display information to users. The normal pause symbol was also placed on the blackboard to serve as a pause button. The board was used for this purpose because it gives an affordance of a noticeboard.

The exit button which is “X” shaped was also place on the door in the virtual lab to give the affordance of walking out from a room. In addition, a blue sprite image was attached to the cardboard lens in order to give users an idea of the object they were currently staring at.

4.2 Tools and Technology

This section give details on the languages, tools and packages going to be used for the implementation of the Virtual Chemistry Lab.

4.2.1 Blender 2.76

Blender is a 3D modelling suite that supports modelling, rigging, animation, simulation, rendering, compositing, motion tracking, video editing and game creation. Blender is an open source tool and was a cheaper but efficient alternative to other 3D modelling software such as Autodesk and Maya which require licenses before they can be used.

4.2.2 Photoshop CC and Gimp

Photoshop is image-editing software developed by Adobe Systems Inc. It will be used to create and edit textures for 3D models. Gimp is also an open-source image manipulation software that would be used to generate bump maps and seamless textures. It is known by most graphic designers and has a large on forum and numerous online tutorials by professionals.

4.2.4 Unity 5.1

A cross-platform game engine developed by Unity Technologies. This is where the application would be developed and built for Android. Unity was chosen because it relatively has a shorter learning curve and also has a large online forum and tutorials.

4.2.4.1 Mecanim Animation System

Mecanim is a sophisticated in-built animation system that comes with Unity by default. Mecanim would be used to animate the 3D models in the scenes. It also creates an animation controller and a finite state machine that allows users trigger when an animation can be played.

4.2.4.2 Shuriken Particle System

A particle system component in Unity that allows users simulates fluid entities such as liquids, clouds and flames by generating and animating large numbers of small 2D images. This particle system would be used to simulate the gases and fire in the Preparation of Ammonia and Test for Gases scenes respectively.

4.2.5 Oddcast Text-to-speech

Oddcast is an online text-to-speech tool. Virtual characters read text aloud in over 25 languages, which can downloaded. Oddcast's was selected because its speech sounded more natural and clearer compared to the others, which sounded very robotic and unnatural.

4.2.6 Cardboard SDKforUnity package

A unity package that provides assets to build a virtual reality application on Android and the iOS. This package is the only available Unity package that enables developers develop virtual reality applications for the Google Cardboard.

4.2.7 Android 5 SDK

The Android SDK provides the necessary tools and kits which allows Unity build an Android Application Kit (.apk) locally on any PC.

4.3 User Interfaces

This section shows the user interface of the application. A detailed description of each interface is provided.

4.3.1 Main Menu:

This is the first interface of the application the user sees and interacts with. In this menu, the user can select the "*Start Experience button*" to move to the next menu, which is the selection menu, or click on "*Exi*t" to close the application.

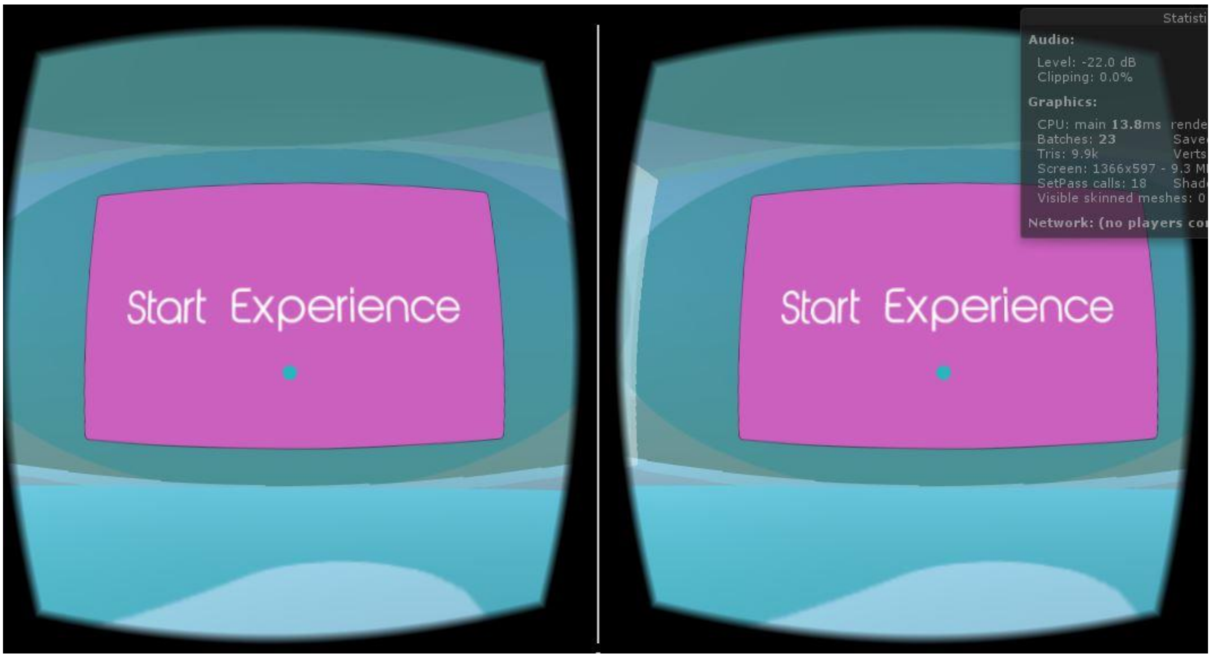

Fig 4.0 Main menu of Virtual Chemistry Lab

4.3.2 Selection Menu

This is the next menu the user sees after clicking with the "*Start Experience*" button. It shows a list of the experiments that are available to be simulated.

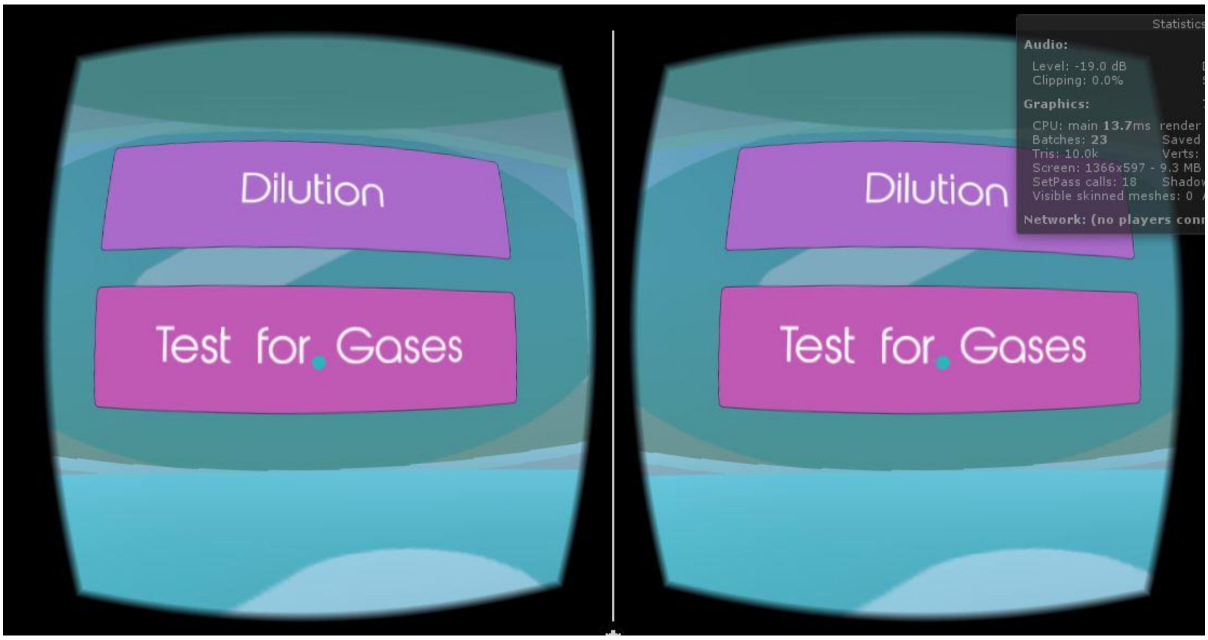

Fig 4.1 Selection menu of the Virtual Chemistry Lab

4.3.3 Simulation Interface

This is an interface seen by the user when one of the experiments in the selection menu is clicked and varies based on selection. Currently, there are 3 simulations to choose from; Dilution, Preparation of Ammonia and Test for Gases.

Fig 4.2 the Dilution Scene

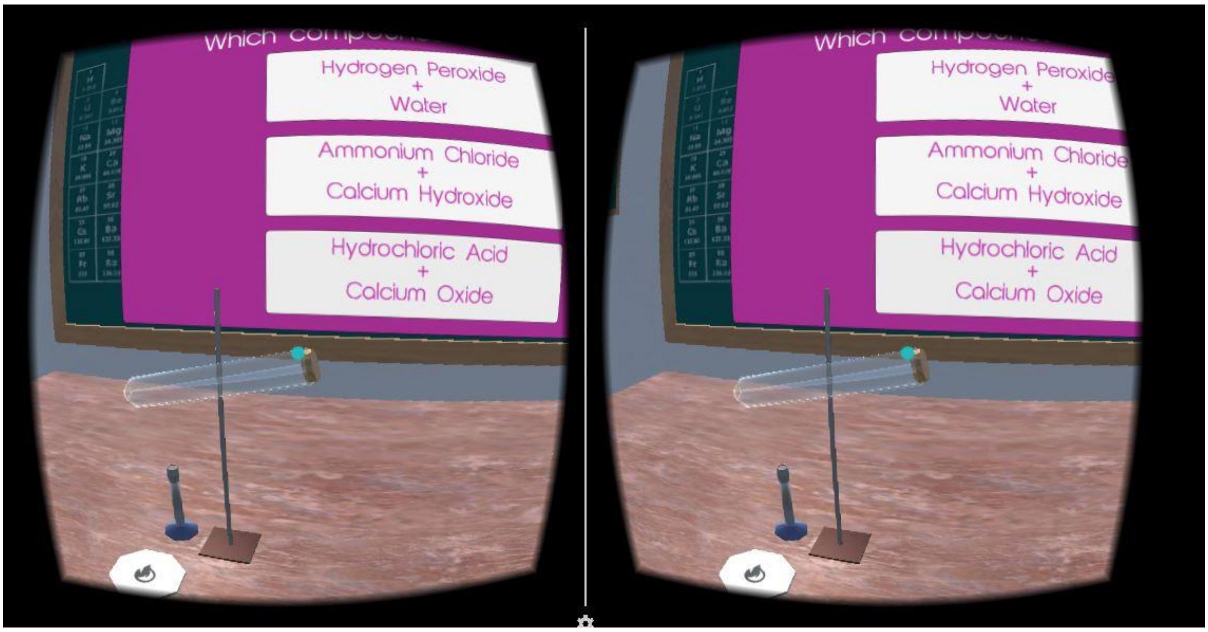

Fig 4.3 the Ammonia Scene

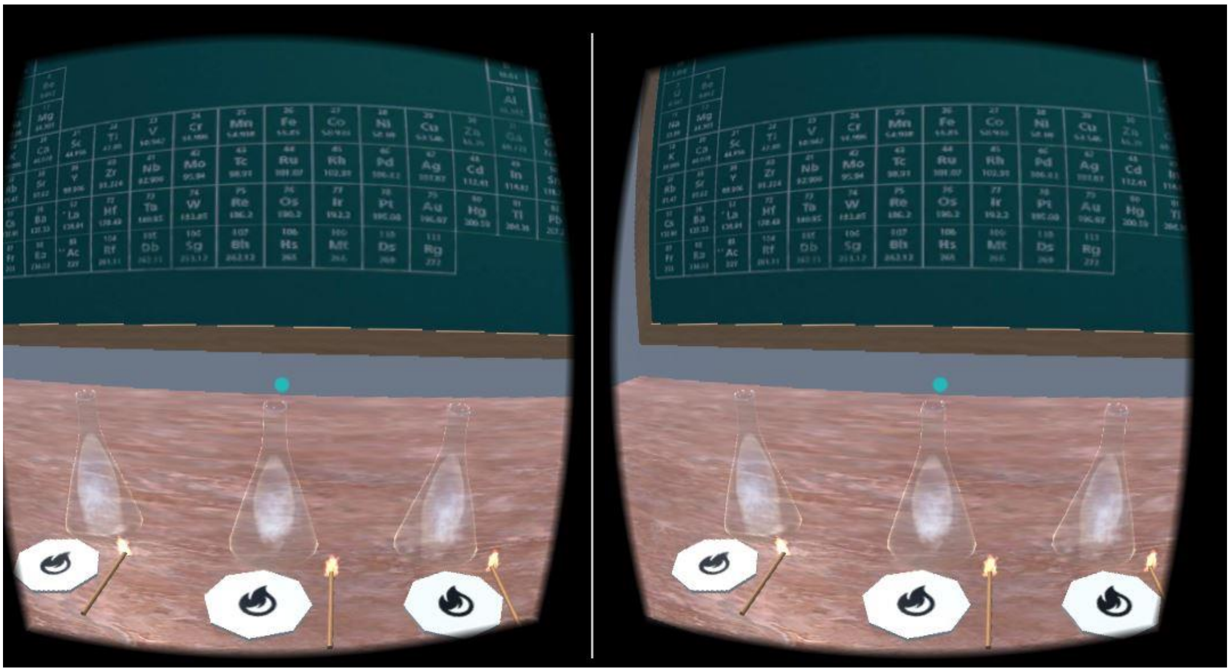

Fig 4.4 the Test for Gases Scene

4.3.4 In-Game Pause Menu

This interface serves as a pause menu for users where they can either exit a simulation or restart it again. This menu is not available in every scene.

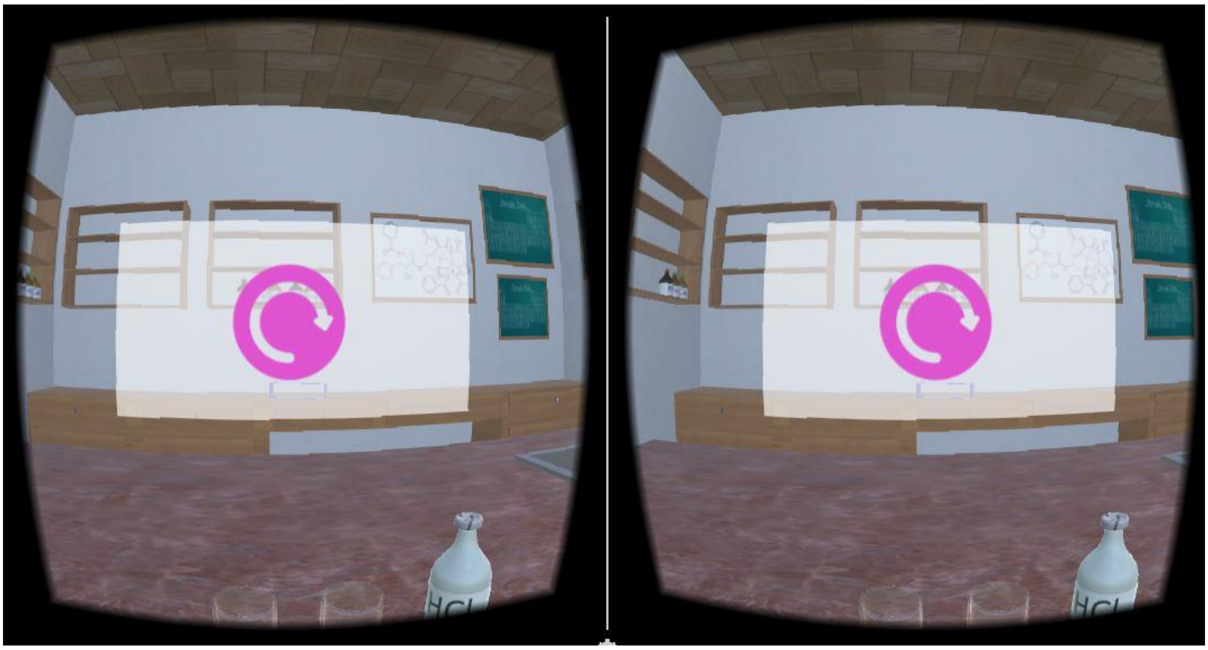

Fig 4.5 the In-Game pause menu: The reset button

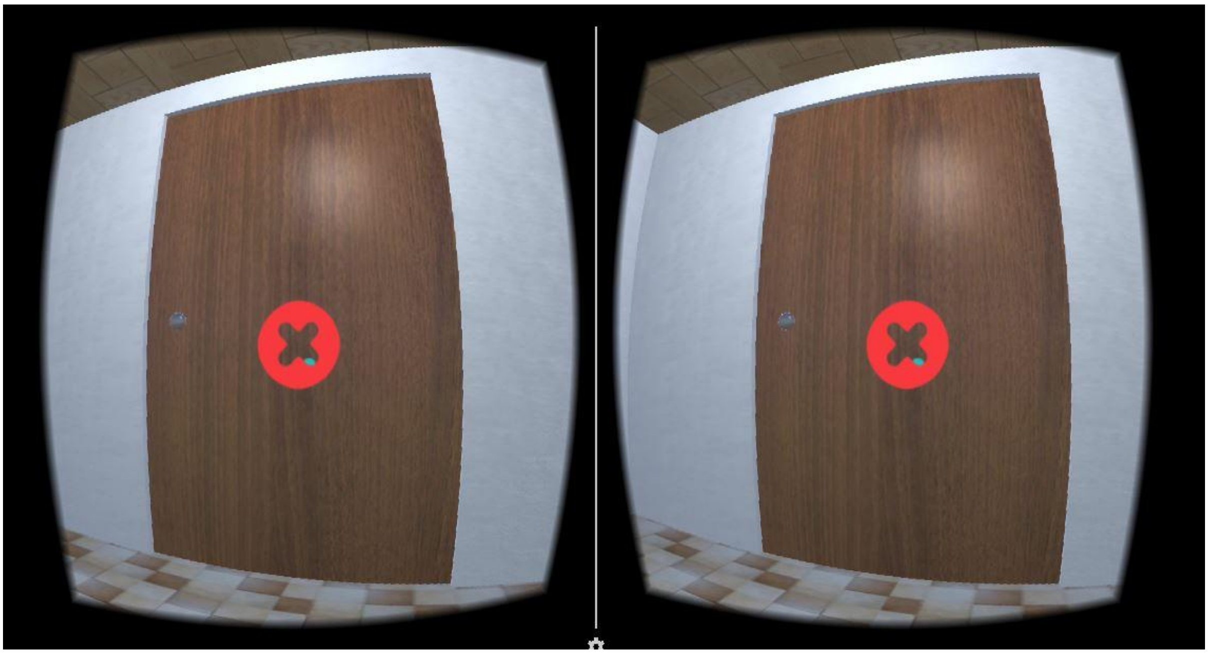

Fig 4.6 the In-Game pause menu: The close button

4.4 Use case diagrams

The application has on main actor, which is the student. The use case diagram below represents the main functional requirements of each student going to use the app.

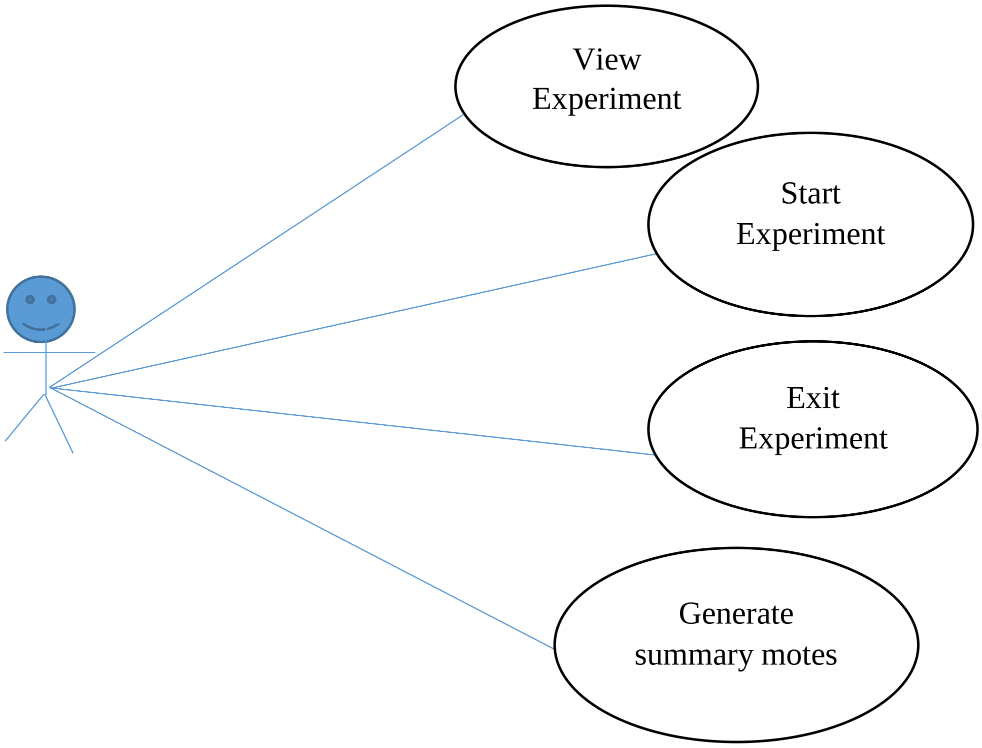

Fig 4.7 Use case diagram of student using the Virtual Chemistry Lab

4.5 Sequence Diagrams

The sequence diagram shows the steps that a user must follow in order to meet all the requirements in the student use-case diagram shown above.

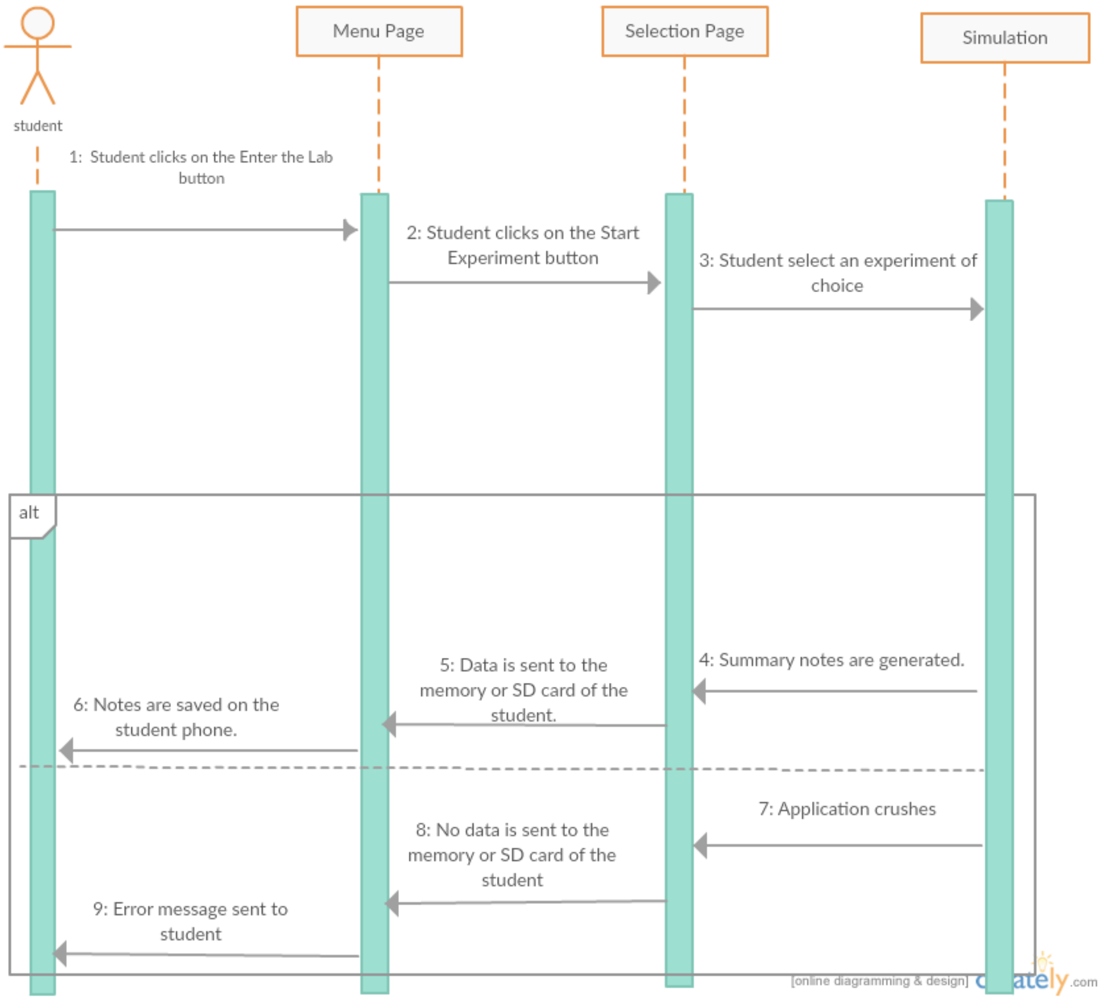

Fig 4.8 Sequence Diagram of the Virtual Chemistry Lab

Chapter 5: Testing and Results

This chapter will focus on the test results and feedback received from testing by both the developer and the users. It would also show the result of the interviews and questionnaires from students of the Ashesi University campus during the development of the application. The main tests carried out were the unit testing, system testing and user testing. The application received an overall rating of 4.02 out of 5 from users. However, it had some side effects on certain users that will be further discussed.

5.1 Unit testing

The application was developed using the agile method of development so it was being tested as it was being developed. There were no automated testing tools used throughout the testing of the script. Each experiment scene was developed separately and tested individually for feedback before the whole application was merged together.

5.1.1 First Build of Virtual Chemistry Lab

The first build of the Virtual Chemistry Lab contained only the Dilution scene and had no sound attached. The trigger was not used as an input device so the user had to stare at object for 5 seconds in order to record an input. The build was first tested in the Unity Editor and tested on a Samsung S6 running Android 5.1.1.

5.1.1.1 Bench Marking and Statistics of First Build

The first build lagged a lot and consumed a large amount of battery power. It had an average Set Pass Call count of 98 -110 draw calls. Set Pass Calls represent how many objects are being drawn to the screen by making calls to the GPU. The higher the number the poorer the performance of the application being developed. The number of calls made to the GPU was high because there were many high poly models in the scene, especially in the background. This was the main cause of the lagging and high power consumption.

Users also found it difficult to navigate around the lab because there were no instructions whatsoever. Another major problem discovered was that the users triggered actions unintentionally because user input was taken by staring at an object for 5 seconds.

5.1.2 Subsequent Builds of Virtual Chemistry Lab

After the first unit test of the application, many changes were made to improve its performance on the Android platform. Many of the non-interactive game objects were taken out of the scene to reduce the number of draw calls made to the GPU. All main models were retopologized to reduce their polygon count and high resolution textures where replaced with lower resolution textures. In addition, the use of normal maps was heavily minimized and no rigid bodies were used in any scene so there were no physics calculations made by the CPU.

The application was then built again and tested in the Unity Editor using the Unity Profiler and also tested on the Samsung S6 running Android 5.1.1.

5.1.2.1 Bench Marking and Statistics of Subsequent Builds

These changes made great improvements in the performance of the application and reduced Set Pass Calls by almost 50%. The average Set Pass Calls made in the Dilution scene was 60 calls. The same modified assets where used to create the Preparation of Ammonia scene and Test for Gases scene. The Preparation of Ammonia of scene recorded an average Set Pass Call of 72 calls while that of the Test for Gases scene was an average of 77 calls. Battery consumption also improved and lasted much longer than the first build. However, in general, the application consumes a lot of battery power and generates a lot of heat because the GPU does twice as much rendering because it renders the view in each lens separately.

5.2 System Testing

The system testing was performed after the all the scenes, which consists of the menu scene, the selection scene, and the simulation scenes made up of the Dilution, Preparation of Ammonia and Test for Gases scenes. All scenes were merged successfully and could be accessed from each other. Set Pass Calls for all the 3 scenes remained the same as recorded in the unit test. However, there were few problems noted during the system test. There is still some amount of lagging and the application sometimes randomly crushes.

5.2.1 System Requirements

The following are the system requirements for the Virtual Chemistry Lab.

Minimum requirements:

- Google Cardboard or a Cardboard headset approved by Google
- A smart phone that runs the Android 5.0 or above.
- Storage space of approximately 22 MB
- Memory allocation of approximately 168 MB

5.3 User Testing and Feedback

The application was tested on student from the Ashesi University campus who had taken either Integrated science Chemistry or Elective Chemistry in their respective Senior High Schools. 12 students were randomly selected and interviewed on their high school experience based on the interview questions in B in the appendix. The application was installed on a Samsung S6 running Android 5.1.1. Users were provided with a Google Cardboard, a phone with the application already installed and earphones. Users were allowed to test the application after filling the questionnaire. 91.6% of the respondents were able to test the successfully. 1 person was not able to test the apps because she felt drowsy.

5.3.1 Feedback

The overall rating of the app by the users was 4.02 out of 5. Most users claimed they had a good user experience while using the app. Most of the feedback given was good while other users had mixed feelings. The UI was quite intuitive for some people and used the in-game instructions to help them navigate the virtual world. Some users also appreciated the audio instructions from the virtual instructor. In general, they liked the immersive nature of the app because it engaged them fully while they also learnt from the simulations. After trying the application, 83.3% of students concluded that students should be more involved in practical sessions when teaching Chemistry in high schools.

However, 2 users were unable to navigate the world with in-game instructions and needed external help. The major problem these users had with the application was dizziness. About 4 users complained of feeling slightly drowsy after trying the application. Others also felt like they were straining their eyes. A major problem with the user interface was identifying the in-game menus such as the pause menu. Users either could not find it or did notice that it had appeared. The cause of this problem is from the nature of virtual reality games in general. In typical games, after the pause button is pressed, the game is paused and the pause menu pops up in front of the screen. In a virtual reality game, the menu appears in the world space so users must look for it in order to access it. In addition, it is never advisable to stop head tracking in a virtual reality game because it can cause drowsiness and motion sickness

According a research by Jorge Serrador, a professor of pharmacology, physiology and neuroscience at Rutgers New Jersey Medical School, virtual reality sickness is caused by the lack of consistency between the visual and vestibular systems. The vestibular system *"works in tandem with the visual system and with the proprioceptive system, integrating sight and sensations from the muscles and joints to tell the brain where the body is in space" (Pappas, 2016).* However, no one knows why this inconsistency causes nausea.

Currently, there are 2 methods that have tried to curb this defect of using virtual reality. Oculus Rift for example increases its refresh rate to reduce lagging when exploring a virtual world. In addition, researchers from the Purdue University have come with a much simpler fix dubbed *"nasum virtualis"*. This is a small cartoon nose is added to the virtual display of a virtual reality game and helps the brain cope with motion sickness. According results presented at the Game Developers Conference in San Francisco, users were able to last 94.2 seconds longer on average without feeling sick when playing slow-paced games. People also lasted 2 seconds longer when playing fast-paced games such as the roller-coaster game.

Another limitation was during the development of the application was that no students currently studying integrated science chemistry or elective chemistry was able to test the application. However, students that were interviewed had taken integrated science chemistry or elective chemistry in senior high school and so helped with providing information from the interviews.

As mentioned earlier, the virtual chemistry lab proved to be cost effective as compared to building physical labs. The cost of a science lab to be constructed by the alma mater of the Kumasi Academy is GHS 1.3 million; 3 of such labs (one for chemistry, biology, physics) would cost a total of GHS 3,900,000 per school. As of 2014, Mr. Samuel Okudzeto, the Minister of Education disclosed that the government would be constructing 50 new Community Day Senior High Schools. Assuming that each school is going to have 3 science labs (one for chemistry, biology, physics), it would cost the government approximately GHS 195 million.

However, virtual labs are easier and much cheaper to setup. Assuming that ideally, there are going to be 100 students in each lab session, 1 Samsung Galaxy S6 currently cost $502.66 and 1 Google Cardboard cost $15 hence, there are going to be 5000 Samsung Galaxy S6s and Google Cardboards needed in total. The cost of providing this is a surprising GHS 9,913,189 compared to GHS 195 million to build physical buildings. Also, one phone can have all 3 virtual labs installed on it.

In addition, based on the feedback from the interview and tests, more than 50% of the users found the application useful for learning.

Chapter 6: Conclusions and Recommendations

This paper described the procedures used in successfully developing the Virtual Chemistry Lab. The application received an overall rating of 4.02 out of 5 from users who tested it. However, the application still needs to go through thorough optimization checks and must strictly follow the rules of the Virtual Reality Design Labs before it can be deployed on the Google Play store. It would also be made compatible for the iOS and be deployed on the AppStore in future. The issue of dizziness would also be tackled in later versions.

In the future, the Virtual Biology and Physics Labs would be developed to also simulate Biology and Physics related experiments to improve the study of both courses in schools.

The app would also have the capability to connect to the internet so that students can share their results with teachers and be graded.

Virtual Reality has many applications in real life and is currently being used in various fields such as in military training, healthcare, entertainment, fashion, heritage and business.

In conclusion, the Virtual Chemistry Lab has been a very successful project and I have challenged myself. I think this application has great potential to revolutionize education in Ghana and motivate developers to come up with more creative ways of solving problems.

References

How did virtual reality begin? (2016, January 18). Retrieved from The Virtual Reality Society: http://www.vrs.org.uk/virtual-reality/beginning.html

Ayitey, C. (2015, August 10). *Over 90,000 WASSCE Candidates Fail Maths and Science.* Retrieved from yen.com.gh: https://yen.com.gh/16909-90000-wassce-candidates-fail-maths-science.html

Bailenson, J. N., Yee, N., Blascovich, J., Beall, A. C., Nicole, L., & Michael, J. (2008). The Use of Immersive Virtual Reality in the Learning Sciences: Digital Transformations of Teachers, Students, and Social Context. *THE JOURNAL OF THE LEARNING SCIENCES*, 102 - 141.

Byrd, W. (2015, June 18). *Innovative use of Virtual Reality in Chemistry Classrooms.* Retrieved from Alchemy Learning: http://alchemylearning.com/innovative-use-of-virtual-reality-in-chemistry-classrooms/

Dott, R. H., & Batten, R. L. (1971). *Evolution of the earth.* New York: McGraw-Hill Inc.

Duke University. (2015). *Duke immersive Virtual Environment.* Retrieved from Duke Uviversity Website: http://virtualreality.duke.edu/project/civil-engineering/

Graphic, D. (2014, January 6). *Past students build science lab for alma mater.* Retrieved from http://www.graphic.com.gh: http://www.graphic.com.gh/news/education/15230-past-students-build-science-lab-for-alma-mater.html

Gyamfi, A. A. (2014, March 3). *Ablakwa: Cost Of New 50 Community SHS Will Range Between GHc 5 & 6.5m Per Building*. Retrieved from news.peacefmonline.com: http://news.peacefmonline.com/pages/education/201403/191820.php

Kabah, P. (2013, August 17th). *Ghana's Education Still Suffers Challenges.* Retrieved from Ghana News Agency: http://www.ghananewsagency.org/features/ghana-s-education-still-suffer-challenges--55115

Norrby, M., Grebner†, C., Eriksson, J., & Boström, J. (2015). Molecular Rift: Virtual Reality for Drug Designers. *Journal of Chemical Information and Modelling*, 2475–2484.

Pappas, S. (2016, April 20). *Why Does Virtual Reality Make Some People Sick?* Retrieved from livescience.com: http://www.livescience.com/54478-why-vr-makes-you-sick.html

Shehata, O. (2015, April 15). *A Beginner's Guide to Coding Graphics Shaders.* Retrieved from Envato tuts+: http://gamedevelopment.tutsplus.com/tutorials/a-beginners-guide-to-coding-graphics-shaders--cms-23313

VR, G. (2016). *Health and Safety.* California: Gear VR.

Yair, Y., Mintz, R., & Litvak, S. (2001). 3D-Virtual Reality in Science Education: An Implication for Astronomy Teaching. *Jl. of Computers in Mathematics and Science Teaching* , 293 - 305.

The United Nations. (1948). *Universal Declaration of Human Rights*.

WAEC. (2010). *Waec Integrated Science Teaching Syllabus*

Appendix

A. Consent Form for the interviews

Please read this consent agreement carefully before you decide to participate in the study.

PURPOSE OF RESEARCH

I would like to ask your permission to be part of a research study on improving the interactivity of chemistry practicals in Ghanaian schools. This research aims at using an app and a virtual reality headset to simulate a virtual chemistry lab where students can perform experiments virtually. The research seeks to find out the good and bad experiences students had when they studied pure or basic chemistry in high school and if virtual reality can improve the study of chemistry in Ghanaian high schools.

VOLUNTARY PARTICIPATION

Your participation in this study is voluntary. Your decision not to participate will not have any negative effect on you or your employment.

POSIBBLE RISKS

I cannot and do not guarantee or promise that you will be at possible risks before, during or after this study.

CONFIDENTIALITY

The results of this research study may be presented on during presentations or meetings with supervisors or published in the project's write-up. Your identity and/or your personal information will not be disclosed in the presentations, meetings and the write-up without your authorization or as required by law.

CONTACT INFORMATION

If you have any questions, concerns or complaints about this research, risks and benefits, contact:

Samuel Akwasi Agyemang

samuel.agyeman @ashesi.edu.gh

If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact my supervisor:

Mr. Kwadwo Osafo-Maafo

kgosafomaafo @ashesi.edu.gh

This research protocol has been reviewed and approved by the Ashesi University Human Subjects Review Committee. If you have questions about the approval process, please contact Chair, Ashesi University HSCR, irb@ashesi.edu.gh

AGREEMENT

I agree to participate in the research study described above

____

Participant Name

____

Participant Signature

_____/_____/_____

Date

You will receive a copy of this form for your record.

B. Interview Questions

- Did you enjoy chemistry in SHS? Why?
- Did you easily understand the concepts and theories in chemistry or found it difficult?
- What made it easy to understand?
- What made it difficult to understand?
- How were experiments conducted in your school?
- How often were they conducted?
- Do you feel you had enough attention from your teacher during the experiments?
- How do you think it can be improved to make the chemistry syllabus more interesting?
- Do you think a virtual chemistry lab would help make chemistry more fun for you?

C. Gantt Chart for the Virtual Chemistry Lab