LOAD CHEMICAL FROM TRUCK TO STORAGE TANK SIMULATION TRAINING USING VIRTUAL REALITY

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LOAD CHEMICAL FROM TRUCK TO STORAGE TANK SIMULATION TRAINING USING VIRTUAL REALITY

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
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ABSTRAK

Dalam persekitaran dengan bahan kimia berbahaya, di mana kesilapan manusia telah terlibat dalam kebanyakan insiden, prestasi manusia adalah penting untuk memastikan keselamatan dan kesihatan. Keberkesanan pemindahan pengetahuan dan kemahiran telah menjadi masalah bagi kedua-dua industri dan ahli akademik. Teknologi untuk realiti maya (VR) semakin popular sebagai cara untuk meningkatkan prestasi manusia. Kajian ini melihat perkara yang diketahui dan dilakukan oleh industri sebelum melaksanakan tugas rutin seperti memuatkan atau memunggah tangki kimia. Tujuan aplikasi latihan ini adalah untuk melatih pengendali dalam industri kimia proses memuatkan bahan kimia dari trak ke tangki simpanan, yang menyediakan pendekatan prosedur maya selain kaedah konvensional seperti berasaskan kelas dan on-the-job-training (OJT). Seterusnya, prosedur bertulis kadangkala sukar diproses oleh pekerja dan menggalakkan mereka untuk mengabaikan langkah penting. Isu lain ialah bahan latihan sedia ada tidak dapat memberi inspirasi kepada banyak situasi, terutamanya yang merangkumi risiko dan bahaya dalam kedua-dua tugas dan modul biasa dan luar biasa yang memerlukan pemantauan tambahan. Oleh kerana perbelanjaan bahan dan peralatan yang tinggi, modul latihan tertentu juga sukar dilaksanakan dengan kerap. Hasilnya, aplikasi latihan VR untuk pemuatan bahan kimia telah dibangunkan untuk memberi pekerja maklumat dan kebolehan yang mereka perlukan untuk memuatkan bahan kimia daripada trak ke dalam tangki simpanan. Pengguna aplikasi latihan ini akan melihat tindakan yang perlu dilakukan untuk menamatkan kursus. Untuk menyelesaikan latihan, pengguna mesti berinteraksi dengan beberapa butang dan item lain yang disertakan dalam senario. Bahaya yang dicetuskan akan setanding dengan yang ada di dunia sebenar, menjadikannya lebih mudah bagi pengguna untuk membiasakannya dan mempunyai pemahaman yang lebih baik tentang keadaan itu. Aplikasi VR ini dibangunkan dengan Unity dan menggunakan metodologi ADDIE. Aplikasi ini telah dinilai dan diuji untuk kefungsian dan keberkesanannya dalam industri kimia. Pekerja akan mendapat pengalaman baru dalam menyertai latihan kehidupan sebenar berkat aplikasi VR ini. Dengan menggabungkan maklumat maya dengan data sebenar, teknologi ini akan membantu pekerja membayangkan dan memahami masalah dengan lebih baik dengan memberikan mereka kandungan multimedia yang kaya dan menarik.

ABSTRACT

In environments with hazardous chemicals, where human error has been implicated in the majority of incidents, human performance is essential to ensuring safety and health. The effectiveness of knowledge and skill transfer has been a problem for both industry and academics. Technology for virtual reality (VR) is gaining popularity as a means of enhancing human performance. This study looks into what the industry knows and does before performing a routine task like loading or unloading a tanker. The purpose of this training application is to train operators in chemical industry the process of unloading chemical from truck to storage tank, which provide virtual procedure approach other than conventional methods such as class-based and on-the-job-training (OJT). Next, written procedures are sometimes hard for the workers to process and encourages them to ignore the important steps. Another issue is that the existing training materials are unable to inspire many situations, particularly those that include risks and hazards in both ordinary and unusual tasks and modules that call for extra monitoring. Due to the high expense of materials and equipment, certain training modules are also difficult to execute often. As a result, a VR training application for chemical loading has been developed to give employees the information and abilities they need to load chemicals from trucks into storage tanks. The users of this training application will see the actions to do in order to finish the course. To finish the training, users must interact with some of the buttons and other items that are included in the scenarios. The hazards triggered will be comparable to those in the actual world, making it simpler for users to become accustomed with it and have a better understanding of the circumstance. This VR application is developed with Unity and using the methodology ADDIE. The application has been evaluated and tested for its functionalities and effectiveness in chemical industry. The workers will have a fresh experience participating in real-life training thanks to this VR application. By fusing virtual information with actual data, this technology will help workers better envision and comprehend the problem by providing them with rich and interesting multimedia contents.

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LIST OF ABBREVIATIONS

VR	Virtual Reality
PPE	Personal Protective Equipment
SDK	Software Development Kit
UI	User Interface

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Virtual reality (VR) has drawn a lot of attention in the modern era and is currently one of the major technological developments. With VR, users may interact with a real-world setting where computer-generated perceptual data has been added to the environment's physical items. This technology makes it possible to experience things that are either not yet created or not yet available in the actual world, such as seeing the surroundings in another dimension. The infinite possibilities of three-dimensional graphics are also free of limitations and boundaries, leaving it open to our own invention and customization (Dwivedi et al., 2022). This technique, which has been successful to this day, has colored the technological landscape in the past few decades.

VR technology is being employed in a variety of industries, including entertainment, education, and military training. Examples of well-known VR products include the video game Beat Saber and Half-Life: Alyx. VR technology has undergone extensive research and development to meet a variety of industry concerns. The workers in industrial settings are required to abide by prescribed procedures. However, there are still human errors involved. In the chemical process industries, 60 to 80 percent of accidents are caused by human error. Over 70% of accidents in the oil and gas sector are the result of human error (Alkhaldi et al., 2017). VR is now a promising technology that potentially address the issue. Virtual reality has various benefits in teaching operators in a range of areas, including power plants, planes, submarines, trains, surgery, and the construction industry, thanks to its advantage of safely simulating the natural world (Dajac & Dela Cruz, 2021). VR also provides a safe online environment where trainees

may practice activities to hone their talents and develop hazard awareness and intervention skills.

The operation of unloading chemicals from trucks and loading them in storage tanks is one of the well-known industrial tasks performed by several companies. One of the industries performing the mentioned activity is Kaneka. Kaneka is a multifaceted company with more than 50 years of experience. It is skilled in the creation of a variety of products, including chemicals, polymers, plastic resins, food, medications, electrical & electronic components, and synthetic fibers. In Gebeng Industrial Estate, Kuantan, Pahang Darul Makmur, Kaneka started manufacturing Impact Modifiers, Expanded Polyethylene and Polypropylene, PVC Paste Resins, Synthetic Fibre Wig, and Polyimide Film in 1995. Chemical activity must be loaded or unloaded correctly in order for the process to proceed without interruption; otherwise, the outcomes are sometimes life-threatening. As a result, a VR Training Application for the activity of loading chemicals from a truck into a storage tank is created to make the process safer and more effective for the operators in the chemical sector. Workers in this project will be given information and skills necessary to load chemicals from trucks into storage tanks through the use of a virtual reality training programme. This application has the ability to attract the attention of the factory management so that they can make sure their employees are aware of the procedure and the risks involved if they skip a step. For instance, a chemical truck explosion in the absence of earth bonding. The users of this training application will see the actions to do in order to finish the course. To finish the training, users must interact with some of the buttons and other items that are included in the scenarios.

1.2 PROBLEM STATEMENTS

More and more training scenarios are being tested using virtual reality, and the results arebeing documented. Studies of the effectiveness of virtual reality on learning retention for real-world application are reported (Carlson et al., 2015) while some reports that the learningretention are equal (Hall et al., 1998). The purpose of this project is to provide user with interactive and immersive experience using virtual reality headset on the safety precautions when loading chemical into liquid bulk tanker before getting into real-world experience. Theproblem is that proper liquid bulk tanker loading is crucial to maintain the quality maintenance of chemicals products and to avoid the serious

consequences toward workers. The workers are required to wear PPE as the best approach to maintain a safe work environment and eliminate any potential hazards (Mendis, 2018) to protect many parts of the body including eyes, face, head, hands, feet and ears. Inhaling product gases can cause various serious health risks. Gases can have acute (unconsciousness, dizziness, chemical burns, organ failure) or chronic (cancer, organ damage, reprotoxic) effects (Guide, 2010) thatcan cause serious shortness of breath after hours of inflation. In order to overcome this, by using this training simulation, workers can reduce the risk of getting serious health risks because they can get beforehand experience.

The next problem is there are lacks of VR applications for training purposes especially in handling chemical products. After some findings, Maintenance Safety (Pipes and Acids) VR Training is a VR application where we can learn how to prepare the tools and safety measures for working on chemical pipeline. Meanwhile, applications like Lab TrainingVR: Personal Protective Equipment Edition is the VR application but is designed to work only on the HTC Vive VR platform. Performing process that involves chemical products can leads to consequences such as loss of lives if no serious equipment inspection is being done. Hence, a VR application that gives worker a beforehand experience is needed to overcome this problem thus reduces the number of possible errors such as picking up wrong object to interact with or failing to follow the task procedure in the right order (Winther et al., 2020).

No	Problem	Description	Effect
1	Workers are exposed to harmful vapors	Proper liquid bulk tanker loading is crucial to maintain the quality maintenance of chemicals products and to avoid the serious consequences toward workers	Inhaling product gases can cause various serious health risks. Gases can have acute (unconsciousness, dizziness, chemical burns, organ failure) or chronic (cancer, organ damage, reprotoxic) effects.

2	Lacks of VR applicationsfor training purposes especially in handling chemical products	Performing process that involves chemical products can lead to consequences such as loss of lives	The number of possible errors such as picking up wrong object to interact with or failing to follow the task procedure in the right order

Table 1.1 Summary of problems faced for workers

1.3 OBJECTIVE

The objectives of this project are as listed below:

i. To study the traditional and VR-based intervention in training simulation for loading chemical from truck to storage tank.

ii. To design and develop a VR application for workers in chemical industry.

iii. To evaluate the functionality and effectiveness of the developed VR application.

1.4 SCOPE

The scope of the project includes user, system and development scope. User scopeis related to the target users of the Load Chemical from Truck to Storage Tank SimulationTraining VR application. This application is designed and developed for workers that involves in loading chemical from truck to storage tank.

System scope is about the systems required in the application. This application is a PC application for Microsoft Windows, developed with VR features and can be played with VR headset. Besides that, this project is a simulation application as it involves training user to load chemical from truck to the storage tank. In this simulation, there will be three different hazard scenarios where user can simulate the explosion of the truck, leakage from hose connection and clear without hazard scenario.

Development scope is about the software and elements used in developing the application. For this project, the software used are Unity and Photoshop. Moreover, there are also multimedia elements implemented into the application such as text, graphics, animation, audio and 3D objects.

1.5 SIGNIFICANCE OF PROJECT

This project is beneficial to the main target user of the application which is the workers and drivers that are involved in loading chemical from truck to storage tank. The workers can use this application to get first-hand experience in an interactive and immersive way using VR technology. This method is different from the traditional method that the workers used to, and enables them to get the experience in a more engaging way.

1.6 REPORT ORGANIZATION

This thesis consists of five chapters in total. Chapter 1 introduces the project, which includes the problem statements, the project's objectives, the scope, the significance of the project and the report organization.

Chapter 2 consists of the literature review of the existing VR application, description and comparison of VR simulation in the industry.

Chapter 3 is about the ADDIE model that has been chosen as the methodology to develop this project. Details about each phase in the model will be explained in this chapter.

Chapter 4 explains the implementation, results, as well as discussion of this project. In this chapter, it will discuss the results that have been obtained during the development and implementation phase.

Last but not least, Chapter 5 is the summary of the obtained results from this project including the constraint and future works that can implemented.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Chapter 2 of this project is about the analysis review of the existing application related to the project title, Loading Chemical from Truck to Storage Tank Simulation Training using VR.

2.2 LITERATURE REVIEW (WORK DESCRIPTION)

In this section, three existing VR applications for VR simulation will be reviewed.

The three applications are Maintenance Safety (Pipes and Acids) VR Training, Lab Training VR: Personal Protective Equipment Edition and VR Health & Safety Trainings for Industry (Base Pack).

2.2.1 Application1: Maintenance Safety (Pipes and Acids) VR Training

Maintenance Safety (Pipes and Acids) VR Training is a VR simulator developed by GWPro for professionals by a team of developers that are consist of NEBOSH certified HSE. This game is available on Steam, which supports Microsoft Windows operating system.

The game has both English and Russian interface and in game audio. In this application, there are eight free modules that you need to play within three hours before the free trial version expires. In this game, movement is by teleport only and there is no snap turning, you have to physically turn your head. Besides that, there are also Training and Exam mode that are locked behind subscription.

Upon starting the game, player is guided with the audio that are being played which will give instructions to player on where to go and the task that needs to be done.

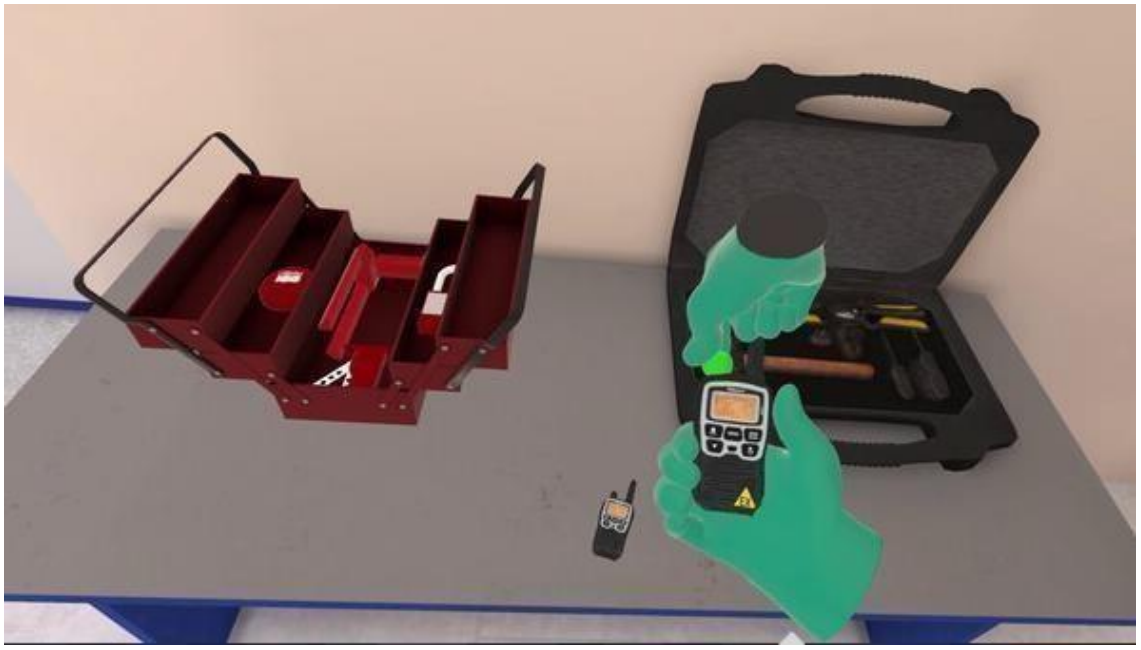


Figure 2.1 Screenshot of interface in Maintenance Safety (Pipes and Acids) VR Training

2.2.2 Application2: Lab Training VR: Personal Protective Equipment Edition

Lab Training VR: Personal Protective Equipment Edition is an VR application developed by Centres for Disease Control and Prevention. It is a virtual reality application that are designed for clinical and public health laboratory professionals, including safety professionals and persons who work with potentially infectious agents in a laboratory.
This application can be downloaded through Steam for Windows Microsoft.

In this application, players can experience on training on how to use VR, how to use PPE properly, and how to reduce risk in a lab where player need to pay attention to detail and listen to feedback get through the risk lab hall. There is a final exam that player have to get 80 percent or better to win, has feedback at end, then they can retake exam. Last but not least, there is some customization that are added to this program like costumes and funny accessories to wear on

your body.

Figure 2.2 Screenshot of interface in Lab Training VR: Personal Protective Equipment Edition

2.2.3 Application 3: VR Health & Safety Trainings for Industry (Base Pack)

The third application, VR Health & Safety Trainings for Industry (Base Pack) is VR simulator developed by GWPro for professionals by a team of developers that are consist of NEBOSH certified HSE and is suitable for a wide variety of workers. This application is available to play on Steam for Microsoft Windows.

In this application, players will be guided through a handful of health and safety protocols. Players also get a tick-list and all you do is follow along with the instructions. The game has six training missions that needs to be finished within three hours but players can extend the playtime by subscribing to the application. Throughout the six training missions, every mission will have three modes which are Study, Training and Exam. The VR movement mode is teleport to fixed points. Player need to grab and interact with the tracked motion controllers.

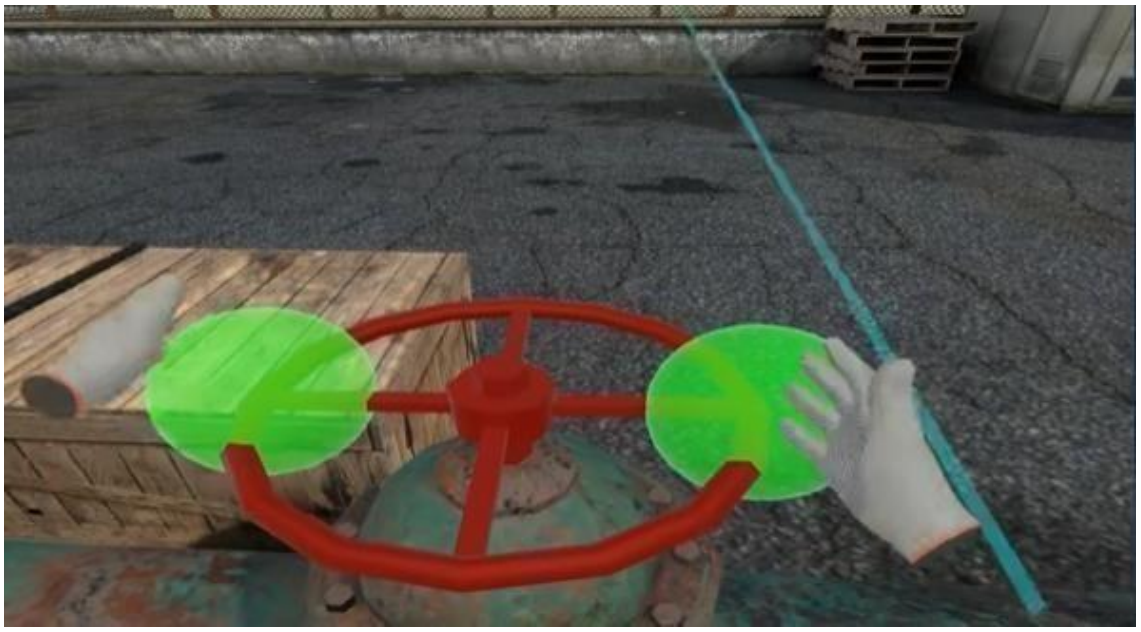


Figure 2.3 Screenshot of interface VR Health & Safety Trainings for Industry (Base Pack)

2.3 LITERATURE REVIEW (WORK RELEVANCY)

Based on the review done earlier, comparison of the three existing applications, which are Maintenance Safety (Pipes and Acids) VR Training, Lab Training VR: Personal Protective Equipment Edition and VR Health & Safety Trainings for Industry (Base Pack) has been formed intro Table 2.1. There are ten aspects taken into comparison, such as Graphical User Interface (GUI), operating system (OS), type of connection, language, target audience, size of application, game engine, topics covered, graphic type as well as functionalities and non-functionalities of the application.Another equally important style is the caption. All captions for figures, tables and equations are formatted using their respective styles prepared in this template.

Table 2.1 Comparison of three existing applications

Application Name	**Maintenance Safety (Pipes and Acids) VR Training**	**Lab Training VR: Personal Protective Equipment**	**VR Health & Safety Trainings for Industry (Base**

		Edition	**Pack)**
Graphical User Interface (GUI)	The interface is simpleand neat.	The interface iscolorful, has animations and easy to understand.	The interface is simpleand easy to understand.
Operating System (OS)	Microsoft Windows	Microsoft Windows	Microsoft Windows
Type of Connection	Offline	Offline	Offline
Language	English, Russian	English	English, Russian
Target Audience	Technician plumbing professionals	Clinical and public health laboratory professionals	Public health laboratory professionals
Game Engine	Unity, OpenVR, SteamworksNET, SDK	Unity, OpenVR, Photon, SDK	Unity, OpenVR, SteamworksNET, SDK
Virtual Reality Feature	None	None	None
Topics Covered	i) Prepare the toolsand safety measures for working on chemical pipeline. ii) Cooperate with your colleagues. iii) Read the pipeline schematics. iv) Provide safety measures around	i) Demonstrate how to do's anddon'ts the appropriate PPEfor daily use at the bench. ii) Demonstrate how to do's and don'ts PPE during an emergency.	i) Handful of healthand safety protocols. ii) Tick-list and allyou do is follow along with the instructions.

	future maintenance work.		
Graphics Type	3D	3D	3D
Functionalities	• Covers tools and safety measures for working on chemical pipelinein English and Russian language. • Has replay ableaudio. • Has Study, Training and Exam modes	• Covers do's anddon'ts the appropriate PPE for daily use at the benchin English language. • Has final exammodes.	• Covers handful of health and safety protocols in English and Russian language. • Has replay able audio. • Has Study, Training and Exam modes.
Non-Functionalities	• User interface is neat and easy to navigate around inthe application. • The application can be played offline by using PC with Microsoft Windows operating systems. • The player needs to pay for subscription in order to play morethan	• User interface is neat, straight-forward and colorful. • The application can be played offline by usingPC with Microsoft Windows operating systems.	• User interface is neat and easy to navigate around inthe application. • The application canbe played offline by using PC with Microsoft Windows operating systems. • The player needs topay for subscription in order to

	three hours.		play more than three hours.

2.4 RELEVANCE OF COMPARISON WITH PROJECT TITLE

After comparing the three applications, it can be concluded that each of the applications has its own advantages and disadvantages. Table 2.2 shows the analysis of the applications.

Application Name	**Maintenance Safety (Pipes and Acids) VR Training**	**Lab Training VR: Personal Protective Equipment Edition**	**VR Health & Safety Trainings for Industry (Base Pack)**
Advantages	• Has full interface and audio that are available in English and Russian. • Clear and replay able audio • Has Training modeand Exam mode.	• High quality graphics andsmooth gameplay. • Player can customize their character's clothes. • Has Final Exammode.	• Has full interface and audio that are available in Englishand Russian. • Clear and replay able audio • Has Training modeand Exam mode.
Disadvantages	• The content of the free	• The application is	• The content of the free

	version is onlylimited for three hours. • Movement can be moved through teleport only. • No snap turning.	only available in English. • The system requirement requires high end PC.	version is only limited for three hours. • Movement can only be moved through teleport only. • No snap turning.

Table 2.2 Advantages and disadvantages of the applications

Based on the literature review that has been done, the table below explains the feature of that sets this proposed VR application different from the existing applications. Loading Chemical from Truck to Storage Tank Simulation Training using VR application fills in the features that the three applications lack to form an application that has the best feature overall.

Existing application	**Loading Chemical from Truck to Storage Tank Simulation Trainingusing VR application**
Maintenance Safety (Pipes and Acids)VR Training • Movement can be moved throughteleport only. • The content of the games can only beplayed up to three hours for the free version.	• Free movement can be controlled usingthe Tracked Motion Controllers. • Can be played for free without limitedtime free trial version.
Lab Training VR: Personal ProtectiveEquipment Edition	• Has training mode where player canpractice their skills they had

• Does not have training mode. • Content only about the demonstrate of PPE.	learned. • The content features the process from the proper wayto equip PPE to loadingliquid into bulk tanker.
VR Health & Safety Trainings forIndustry (Base Pack) • Movement can be moved through teleport only.	• Free movement can be controlled usingthe Tracked Motion Controllers. • Can be played for free without limitedtime free trial version.

Table 2.3 Comparison between the features in the existing application and the proposed application

2.5 SUMMARY

In order to develop a new game with and existing category requires the developer to make research and survey of the existing game within the same category. From this initiative, the developer gets to obtains the main problems that are happening within the VR application category and able to develop a VR application that complements the existing game. Even the small details, achievements, problems from the previousor existing game are able to give an opportunity to improve the newly developed game. Research shows that VR application is most suitable to be played on PC because the requirement to runs the Unity with the best quality and features. It also shows that audios, texts, graphics and animation is the most crucial elements in developing a VR simulation game where it can attract the user attention and make the user experience more immersive as similar to the real-world appliance.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the methodology that has been chosen to develop this project will be explained in detail. This methodology will help to make sure the development process will progress smoothly according to the timeframe. For this project, ADDIE model has been chosen as the methodology.

3.2 PROJECT MANAGEMENT FRAMEWORK

ADDIE model has five phases in total (Analysis, Design, Development, Implementation and Evaluation). This methodology was chosen because it has a greater rate of success, is capable of returning to a prior phase, and can adapt to changing requirements. Analysis, design, development, implementation, and evaluation make up the five steps of ADDIE. To ensure that the development process is kept under control, this methodology is employed as a guide. This will make it easier to design the application while staying within the constraints of the project, allowing it to be finished on schedule and within budget. The benefit of using the ADDIE technique is that it is adaptable, allowing for the execution and planning of various process phases at the user's discretion. This model is typically flexible to user requirements.

3.2.1 ANALYSIS

Phase one of the project development involves analysis. By examining the issues and the best solutions at this phase, the project's training aim may be clearly determined. In addition, this phase includes determining the project's target audience, its scope, and researching the current systems or applications. Additionally, it's crucial to identify the needs for the application at this phase in order to choose the best way of audience distribution and to design the best

approach to developing and delivering the project. Analysis makes the project's goals clearer and aids in the developer's understanding of the expected results upon project completion. The next stage of the ADDIE model can be started by the developer when this one is finished.

3.2.2 DESIGN

The application's content and the method through which it will be delivered to the end user are both carefully planned during the design process. Designing is crucial for the programme to function properly and to satisfy all needs. Creating a storyboard, making drawings, and obtaining data for the application's content are just a few of the tasks completed during this phase. The application's content may discuss the many media kinds that will be utilised, including images, audio, and other graphics; however, for this project, it mostly focuses on target markers and audio as the VR component. In addition, the Design phase is a critical step in the development process since it determines how appealing the application will be and if it will catch the attention of users in this industry. To proceed to the following stage, it is crucial to be thoroughly prepared.

3.2.3 DEVELOPMENT

In the development phase, the project's production begun. The information gathered from the earlier phases will be used in this step to build the application that can meet the requirements. Making sure the development activities are progressing along the project's schedule is crucial throughout the development phase. This is done to ensure that the project can be completed on schedule and that the requirements and project objectives are met. Several programmes, including Unity, Adobe Photoshop, and Audacity, will be utilised during this phase to construct various application features. The actual VR feature itself, visuals, and music are a few examples of the aspects.

3.2.4 IMPLEMENTATION

The application will be continuously modified throughout this phase to ensure optimal functionality and the creation of the best version of the application.

Throughout this period, any bugs or errors discovered during testing will be continuously fixed.

3.2.5 EVALUATION

Evaluation phase are divided into two parts which are formative and summative evaluation. Evaluation that presents at each stage of phase is known as formative evaluation. While, summative evaluation is tests designed for users after they use the VR application to measure the functionality of the application. Any change or improvement on the VR application is based on the feedbacks from users. User Acceptance Test (UAT) is used to test the features' functionality in the VR application. In this phase, the revision of the VR application will also be carrying out.

3.3 PROJECT REQUIREMENT

Table 3.1 shows the requirements for this project in terms of Functional Requirements, Non-Functional Requirements, Constraints and Limitations.

Table 3.1 Project Requirement

Functional Requirements	• The application should demonstrate the process of wearing PPE equipment and loading chemical to liquid bulk tanker. • The application should support the controls of Tracked Motion Controllers. • The application should be able to be seen through VR headset. • The process must be cleared without leakage in order to proceed to next stage. • User is able to quit the VR application.

Non-Functional Requirements	• The movement of the character should be as what player directed (front button should make the character goes forward). • The application should be able to play in PC with Microsoft Windows operating systems. • The interface of the application is simple and easy to understand.
Constraints and Limitations	• The application can only be played on PC only. • The movements of the character are restricted only using Tracked Motion Controllers.

3.4 PROPOSED DESIGN

Proposed design for this application will be represented in diagrams like Context Diagram, Use Case diagram and Activity diagram. Each diagram comes with a brief description.

3.4.1 CONTECT DIAGRAM

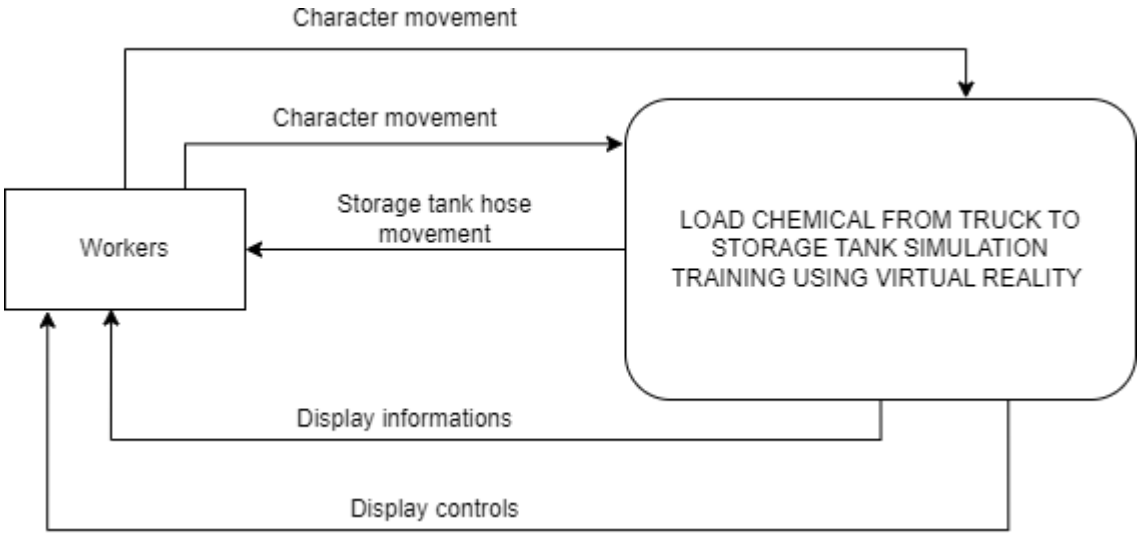


Figure 3.1 Context Diagram

3.4.2 USE CASE DIAGRAM

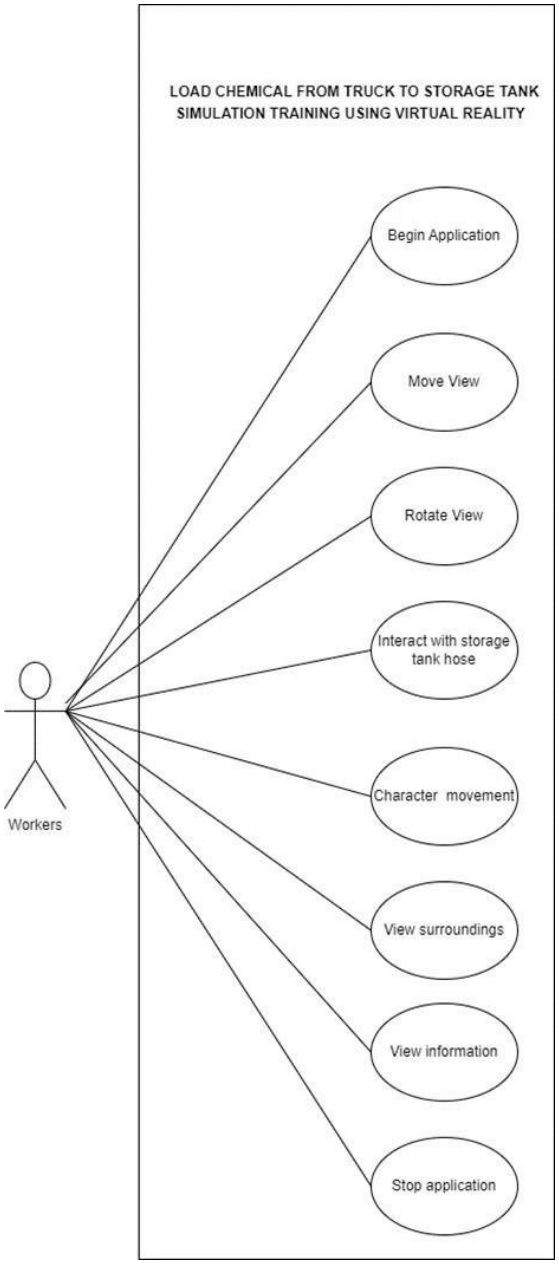


Figure 3.2 Use case diagram

3.4.3 FLOWCHART

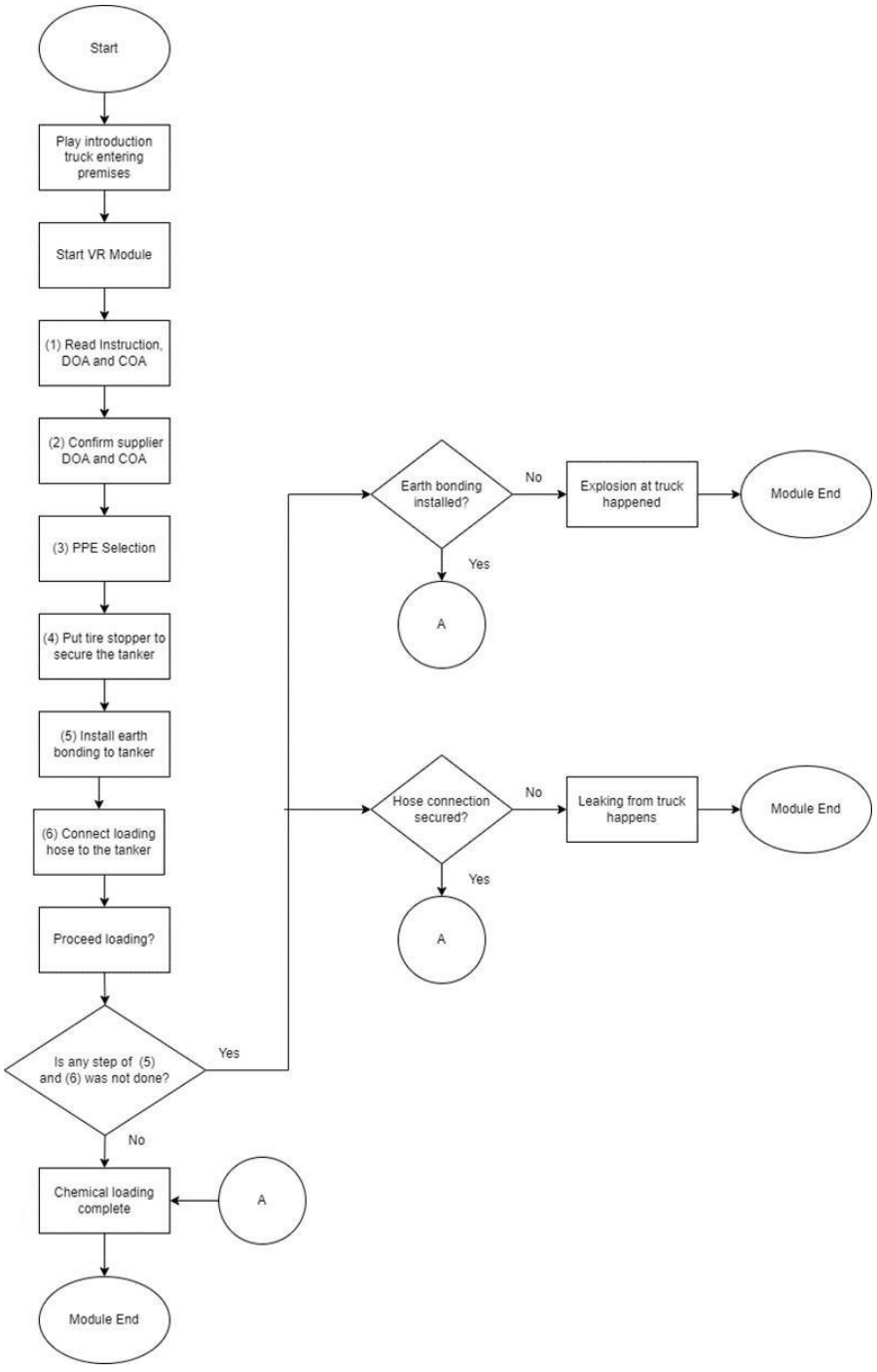
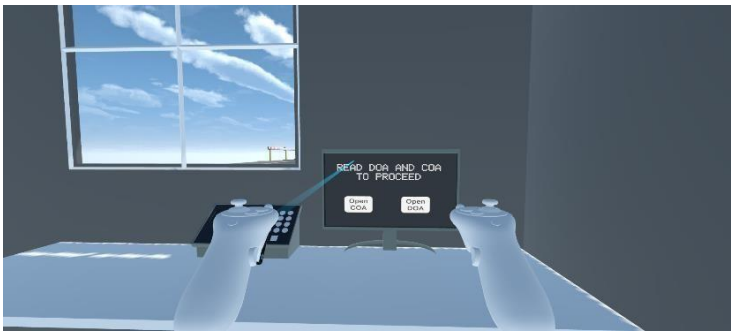


Figure 3.3 FLOWCHART

3.4.4 STORYBOARD

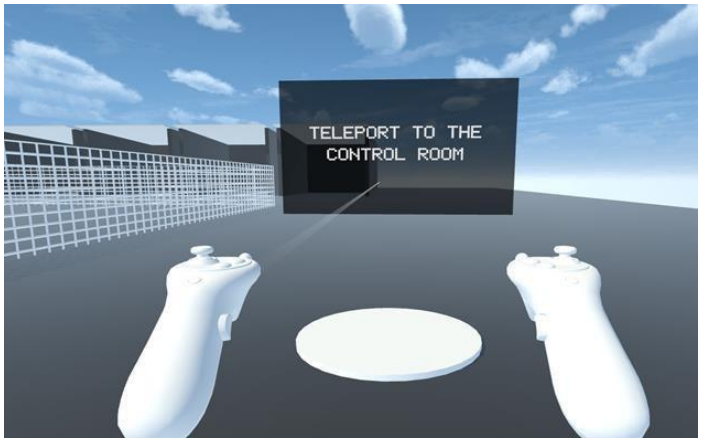
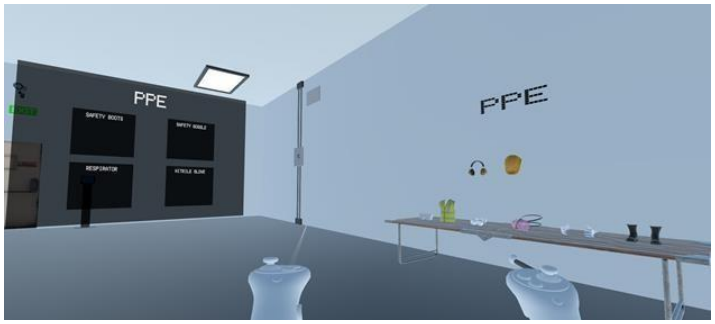
Interface	Description
 When the user opens the application, user will be displaying the main menu scene where user can press the‘PLAY’ button to navigate to next scene. User also can press the ‘QUIT’ button to close the application. A setting button is located at the top right of the screen where user can change the volume of the application.	Main Menu Scene - Text: Load Chemical from Truck to StorageTank Simulation Training Using Virtual Reality - Buttons: “PLAY” will allowthe user to navigateto next scene. “QUIT” will allow the user to close the application.
	Animation : Video

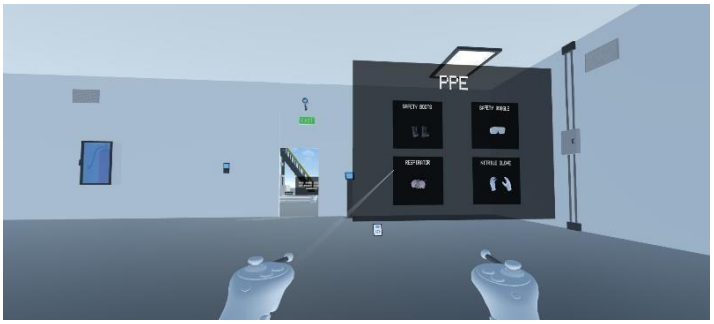
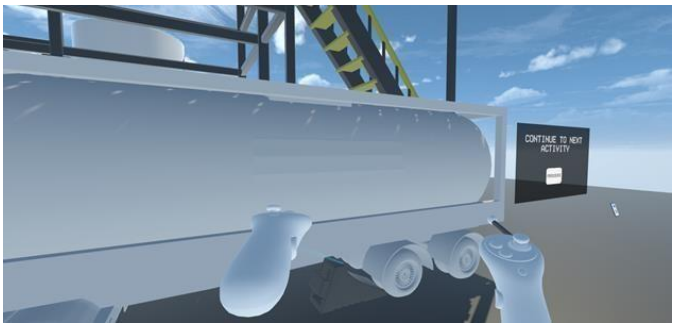
An animation of truck entering the scene will be playing. After that, the user will be directed to next scene, Weight Bridge.

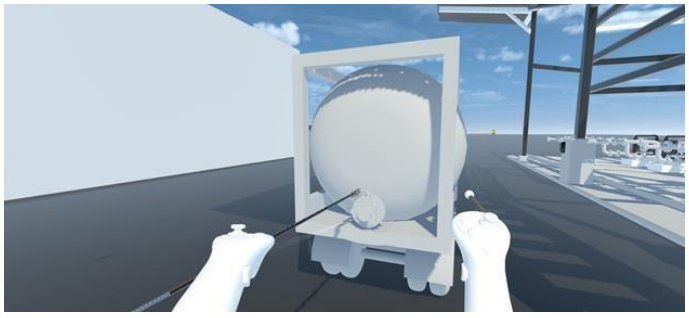
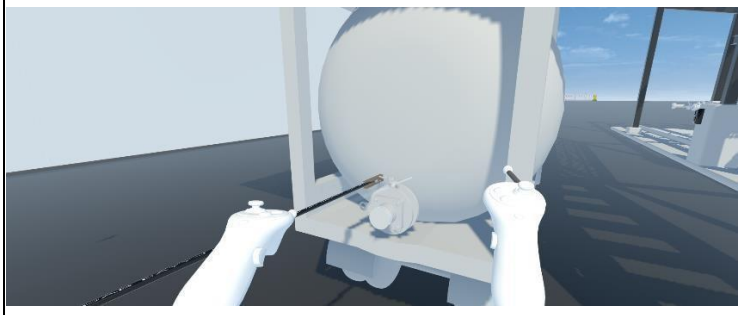


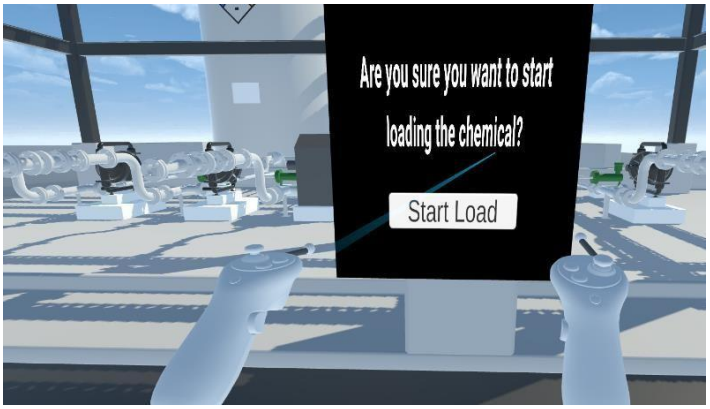
At the weight bridge, user need to read the DOA and COAbefore proceed to the next scene.

- Text: Instructions to proceed
- Buttons: Open COA

 Then, user need to teleport to the control room by using the white mat on the floor.	
 User need to drag the correct 4 PPE items into the item box. If they manage to get all the PPE, the door will open for them and can proceed to the next scene. However, if select the wrong PPE, the door won't open.	- Text: PPE Inventory - Box

	
 User need to add tire stopper to secure the tanker in order to proceed to next scene.	
 User can click on the instruction icon to read the steps to complete the training.	Text: Instruction 1. Confirm supplier DOA and COA (Weight Bridge Room) 2. PPE Selection (Control Room) 3. Put tire stopper (Loading Area) 4. Install

	earth bonding (Loading Area) 5. Connect liquid hose to truck (Loading Area) 6. Load the chemical intro truck (Loading Area)
 User need to connect earth bonding in order to make sure that there will be no explosion happened during loading process.	
 User also need to connect loading hose in order to make sure there will be no leakage during the loading process.	



User then need to start loading the chemical into the truck for the simulation to continue by clicking on the ‘Start Load’ button.

If the user successfully connects the loading hose and earth cable with the truck, the success UI will be shown and user can choose to continue to main menu by clicking on the ‘Retry’ button or close the application by clicking on ‘Quit’.

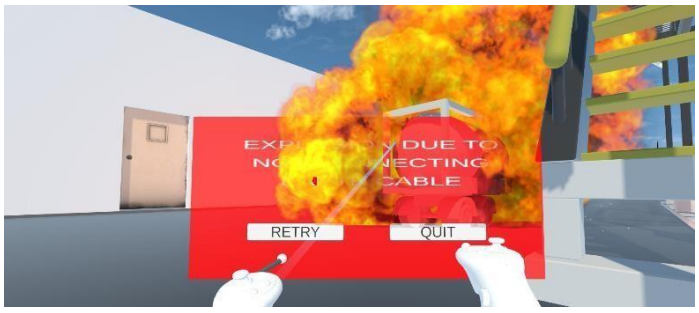
 However, if the user did not connect the loading hose with the truck, a failure UI will be shown indicating that there is leakage happened and user can choose to go main menu by clicking on 'Retry' button or close the application by clicking on 'Quit' button.	
 If the user did not connect the earth bonding with the truck, a failure UI will be shown indicating that there is explosion happened and user can choose to go main menu by clicking on 'Retry' button or close the application by clicking on 'Quit' button.	

Table 3.2 Storyboard

3.5 DATA DESIGN

This application is developed by using Unity and for Virtual Reality to work, Unity is also used together with a software development kit (SDK) named XR Interaction Toolkit. XR Interaction Toolkit is a flexible, component-based interaction solution for building VR experiences. It offers a framework that enables Unity input events to be used for 3D and UI interactions. The Interaction Manager, which connects these two types of components, and a set of basic Interactor and Interactable components make up the system's core. The assets that will be used to develop Load Chemical from Truck to Storage Tank Simulation Training Using Virtual Reality are 3D Truck, 3D Hose, 3D PPE Equipment, 3D Chemical Liquid, 3D Liquid Tank and the environment consist of a 3D Room for the Wear Equipment Training.

3.6 TESTING PLAN

To ensure the application's functionality and features fulfilled the requirements, a testing and validation plan has to be constructed. For this application, User Acceptance Test (UAT) is chosen as the testing plan. This test will be conducted by training where the activities and status are being reviewed.

No.	Module	Activities	Status		Comments
1.	Wearing PPE Equipment	Hi vis vest	Yes	No	
2.		Safety footwear	Yes	No	
3.		Safety headphones	Yes	No	
4.		Eye goggle	Yes	No	
5.		Safety helmet	Yes	No	
6.		Respirator	Yes	No	

7.		Safety goggle	Yes	No	
8.		Gloves	Yes	No	
9.	Load Chemical from Truck to Storage Tank Training	Earth cable connected	Yes	No	
10.		Loading hose connected	Yes	No	
11.	Hazard Simulation	Explosion happened	Yes	No	
12.		Leakage happened	Yes	No	

Table 3.3 Testing Plan

3.7 POTENTIAL USE OD TH E PROPOSED SOLUTION

This application is designed in hope to create a safer initiative for workers that involved in loading chemical from truck to storage tank. With the evolution of technology, workers may get the first-hand experience without being at risk of being exposed to chemical irritation on their skin. This application has the potential to provide an immersive and engaging way for the workers where they can use the training anytime as long as they have a laptop or PC that supports VR controller. Furthermore, this application can further be improved by collaborating with companies that expertise in the process of loading chemical from truck to storage tank as it can help this application to reach more audiences.

3.8 GANTT CHART

CD19094 PSM1			DURATION (days)
START DATE	END DATE	DESCRIPTION	
10/14/22	10/18/22	**Introduction**	4
10/14/22	10/18/22	Introduction	4
10/19/22	10/22/22	Problem Statement	3
10/23/22	10/27/22	Objectives	4
10/28/22	11/11/22	Summary	13
11/12/22	11/14/22	Scope	2
11/15/22	11/30/22	**Literature Review**	15
11/15/22	11/20/22	Introduction	5
11/21/22	11/23/22	Identify existing application	2
11/24/22	11/28/22	Comparison existing application	4
11/29/22	11/30/22	Summary	1
12/1/22	1/19/23	**Methodology**	48
12/1/22	12/3/22	Introduction	2
12/4/22	12/10/22	Project Management Framework	6
12/13/22	12/17/22	Analysis	4
12/18/22	12/21/22	Project Requirement	3
12/22/22	12/25/22	Propose Design	3
12/26/22	12/29/22	Data Design	3
12/30/22	1/14/23	Testing	14
1/15/23	1/18/23	Potential Use of Proposed Solution	3

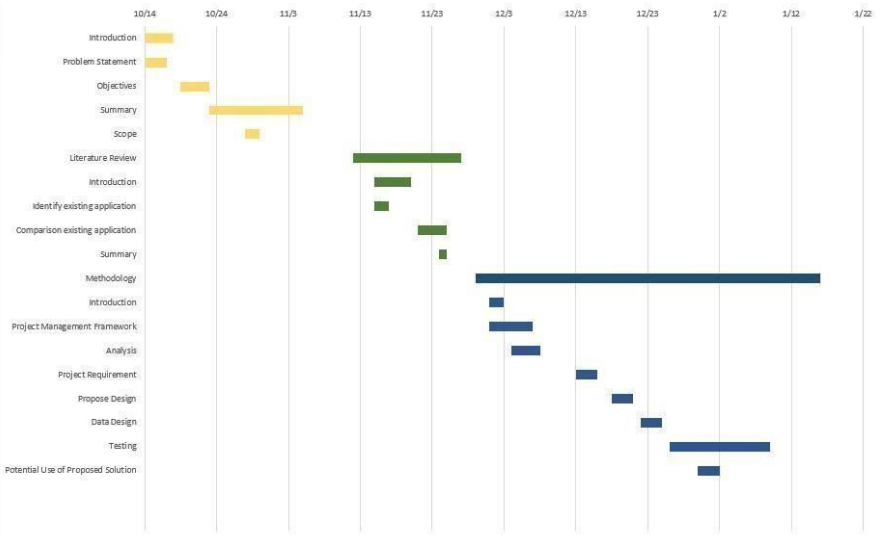


Figure 3.4 GANTT CHART

CHAPTER 4

IMPLEMENTATION, RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will go over the Load Chemical from Truck to Storage Tank Simulation Training Using Virtual Reality development process in detail. The implementation, testing and result analysis are the processes involved. The results of the finding based on the result of the testing justified towards the end of this chapter which aligns with the project objectives. Software that are used to develop this application are using Unity(2021.3.16f1) and Microsoft Visual Studio 2019.

4.2 DEVELOPMENT TOOLS

No.	Tools	Purpose
1	Unity 	To create the scene, environment, training content and training controls.
2	Microsoft Visual Studio 2019 	Used to write the C# scripting for the trucks and control of player.

3	Canva 	Used to make images for icons.
4	Unity Asset Store 	To find any related assets that can be used for the project.

Table 4.1 Development tools table

4.3 IMPLEMENTATION

This section outlines the methods and implementation requirements. The steps taken in the project development process are documented. The first part of this system is its development environment, and the second part is its functioning. Both parts will be covered in depth.

4.3.1 Designing Graphics and Multimedia Contents

The multimedia elements such as main menu background is designed using Canva. Figure 4.1 shows the main menu background that are used for the project.

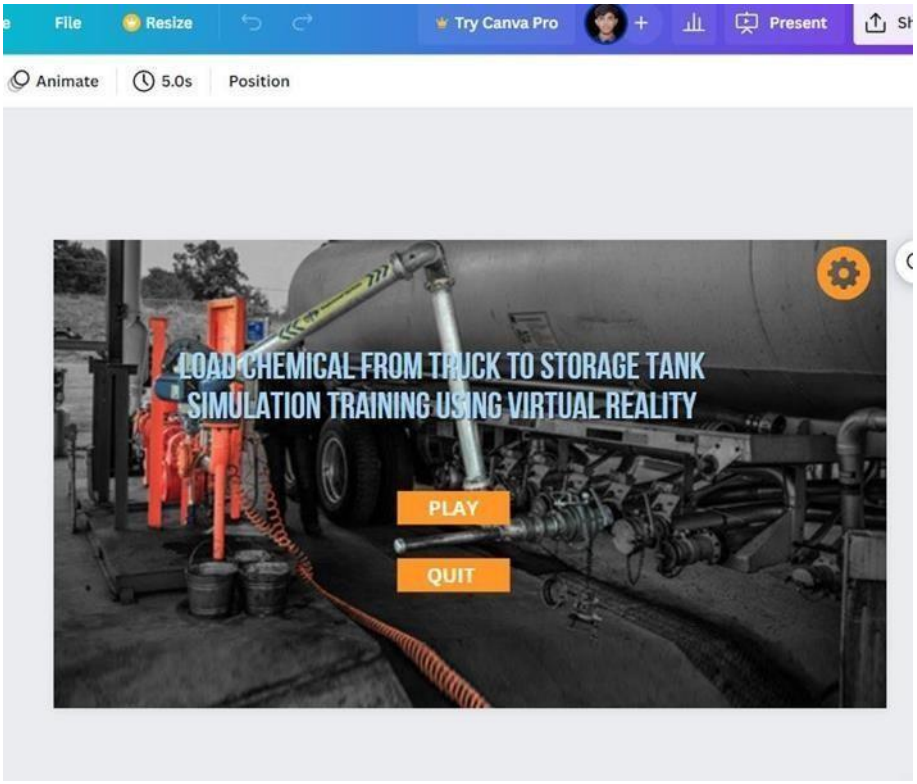


Figure 4.1 Main Menu using Canva

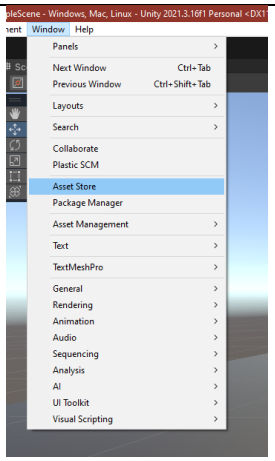
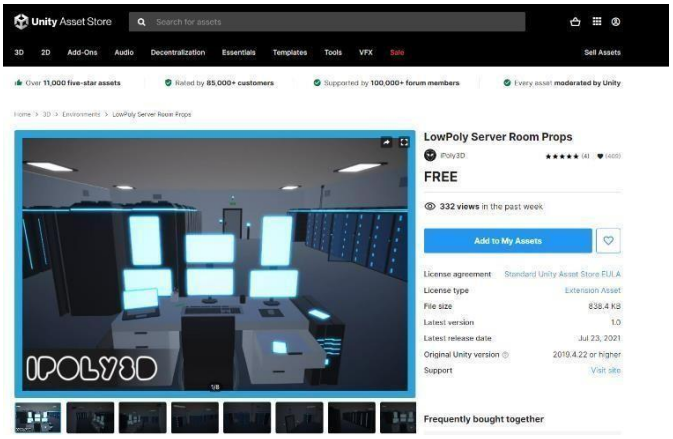
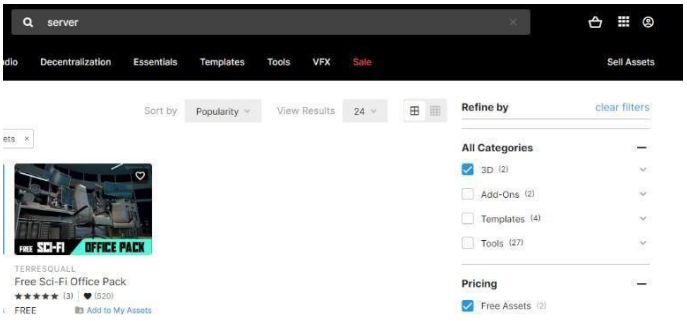
4.3.2 Development of the Training Application

The development of the training application starts with finding the relatable assets in Unity Asset Store.

4.3.2.1 Unity Assets Store

All of the assets that will be required for developing this game may be located in the unity assets store before beginning the application's development. Unity assets store straight from Unity.

No	Image	Description

1	 	On Unity Go to window -> Asset Store: The Unity Asset Store will automatically be opened on a new web browser.
2		Set the categories as 3D as the training system is in 3D application and set the pricing to ‘Free Assets’.

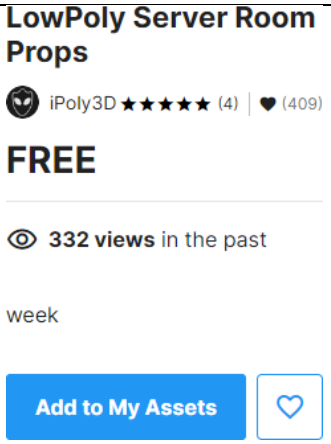
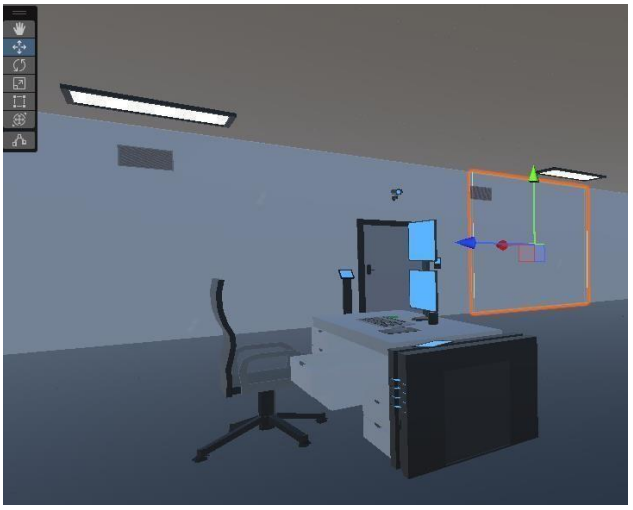
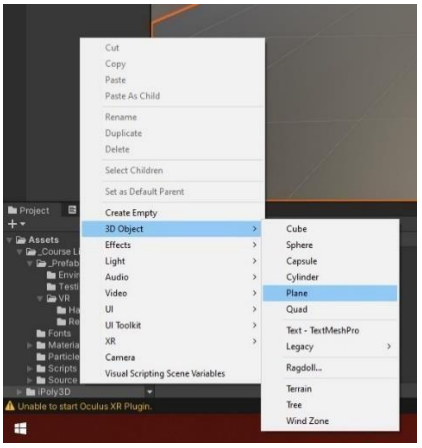
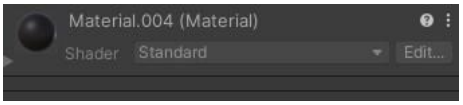
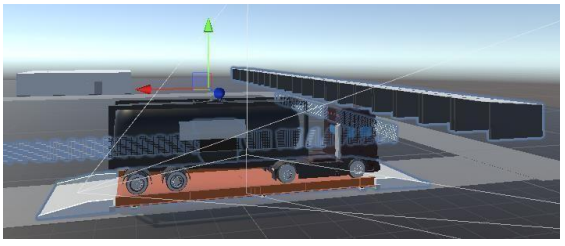
3		After going through the asset store, LowPoly Server Room is the most suitable asset for this application due to free pricing and suitable design.
4		After importing and download the asset that just downloaded into the Unity project, drag the asset into the scene

Table 4.2 Unity Assets Store

4.3.2.2 Environment of the Training Application

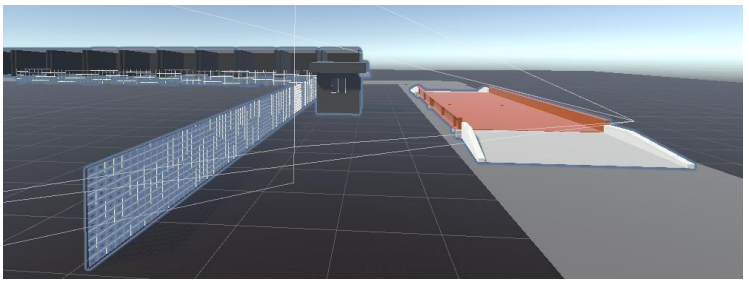
The environment is made using the assets provided by Dr Tuty Asmawati which are made using Blender.

No	Image	Description
1		First of all, create the base floor of the environment using 3D object -> Plane.
2		Then, assign the material to the floor to make the floor more visible from other assets.
3		Place the assets such as weighing bridge and truck according to the

		proposed flowchart.

Table 4.3 Environment of the Training Application

4.3.2.3 Assets Used

No	Image	Description
1	Weighing Bridge 	On the weighing bridge, there will be a written information on what the user should done such as weight inspection of the truck and checking the COA before proceed to next step.
2	Loading Area	On the loading area, video of operator communicating to DCS will be played.User also need to place stopped at the tire of the truck to

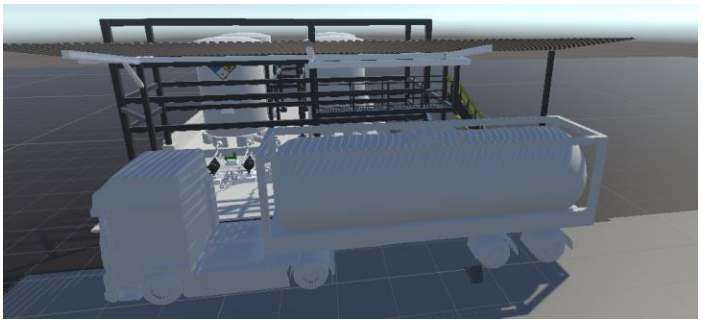
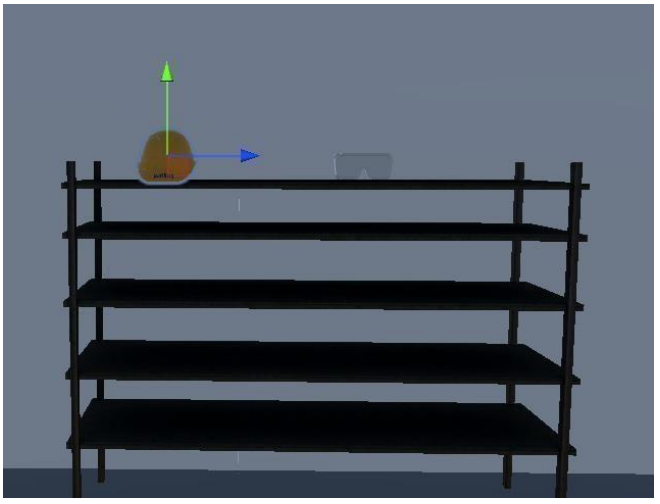
		secure the tanker during loading process. A few otheractivities will be conducted here such as unlocking the pump manual valve and connecting flexible hose to tanker.
3	Control Room 	When user enter control room, they are required to verify the amount to load the chemical into the truck. User also will need to select the correct PPE from the PPE locker room located inside control room.

Table 4.4 Assets Used

4.3.2.4 Application Interfaces

The interfaces for the application are made using XR UI Canvas from Unity as shown in Figure 4.2. There will also be a button made using XR UI Button where the canvas will disappear once user press the OK button.

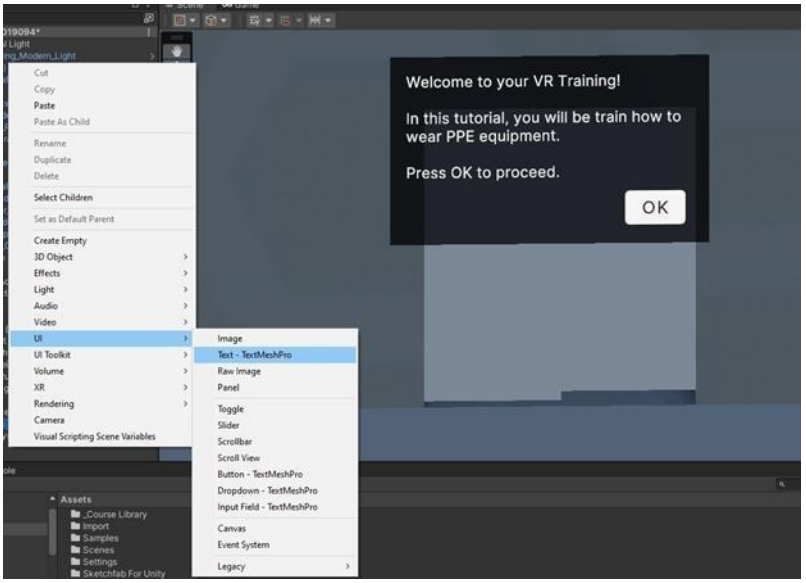


Figure 4.2 Welcome User Interface

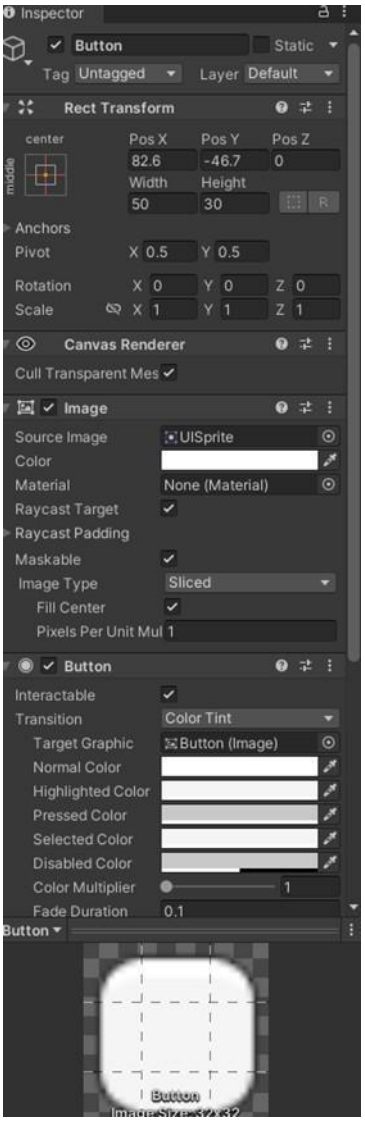


Figure 4.3 Welcome XR Canvas when user start the application.

4.3.2.5 Main Menu Scene

Figure 4.4 shows the starting scene of the VR application where the main menu consists of two buttons which is ‘Start’ and ‘Quit’. If the user clicks on the ‘Start’ button then they will be redirected to the next scene which the truck entering the site scene while ‘Quit’ button allows user to close the training application.

Figure 4.4 Main Menu

4.3.2.6 Chemical truck entering site Scene

After user click ‘Start’ in the Main Menu scene, a short cut scene of truck entering the scene and stopping at the weight bridge is shown as in Figure 4.5. After the scene ends, a text ‘Loading Chemical Simulation Begin’ are shown to indicate the simulation begin.

Figure 4.5 Truck Entering Site Scene

4.3.2.7 PPE Selection Scene

In the control room, there are various equipment that are located on the table and user needs to grab the suitable PPE equipment and put them into the specific table with their respective names on it as shown in Figure 4.6.

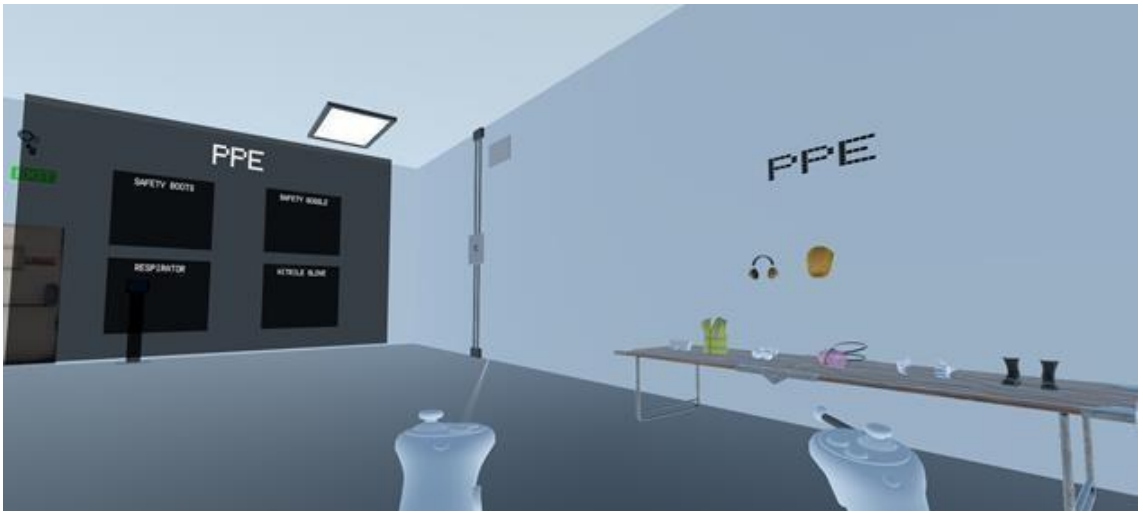


Figure 4.6 PPE selection

If the user correctly places all four of the PPE equipment into their table with right label on it, then the door will open and user can proceed to the next scene as shown in Figure 4.7.

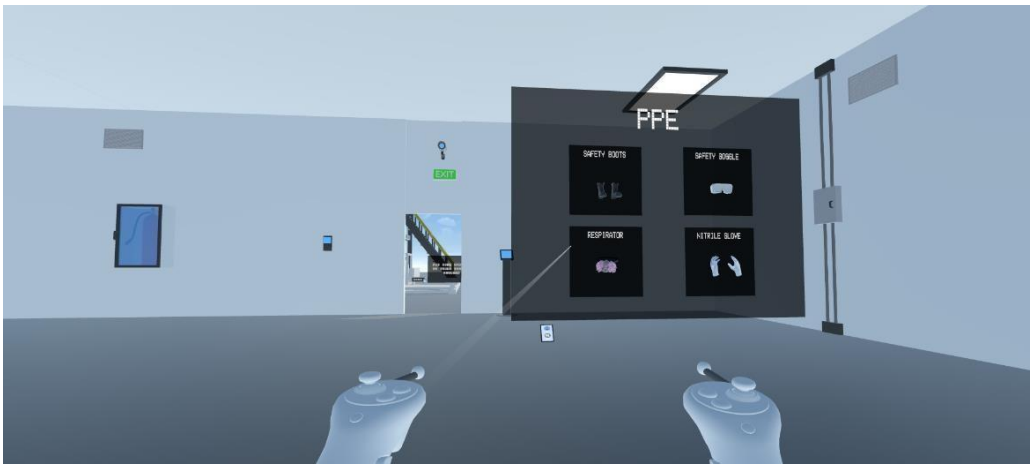


Figure 4.7 Correct PPE Selection

4.3.2.8 Put Tyre Stopper on Truck

User then need to put the tyre stopper on the truck's tyre in order to proceed to the next scene which is the loading chemical into the truck scene.

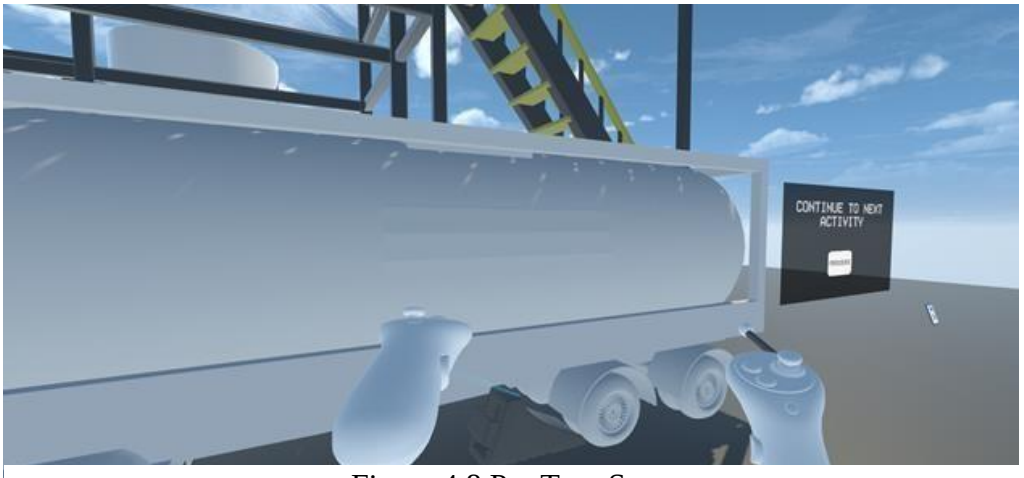


Figure 4.8 Put Tyre Stopper

4.3.2.9 Connect Earth Cable to Truck Scene

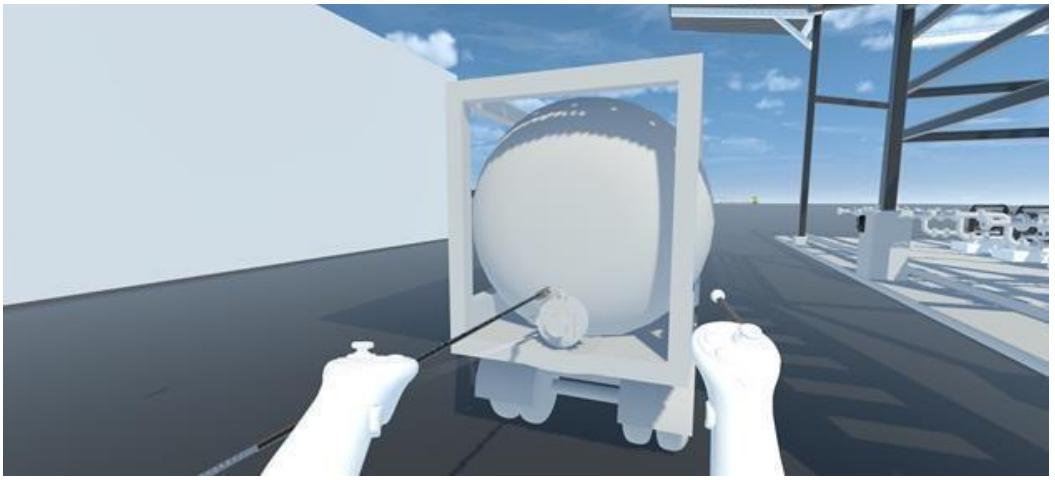


Figure 4.9 Connect Earth Cable

Then, user is required to connect the earth cable with the truck by grabbing the earth cable that are located on the loading site.

4.3.2.10 Connect Loading Hose to Truck Scene

After that, user is required to connect the loading hose with the truck by grabbing the hose that are located on the loading site and connect it to the back of the truck.

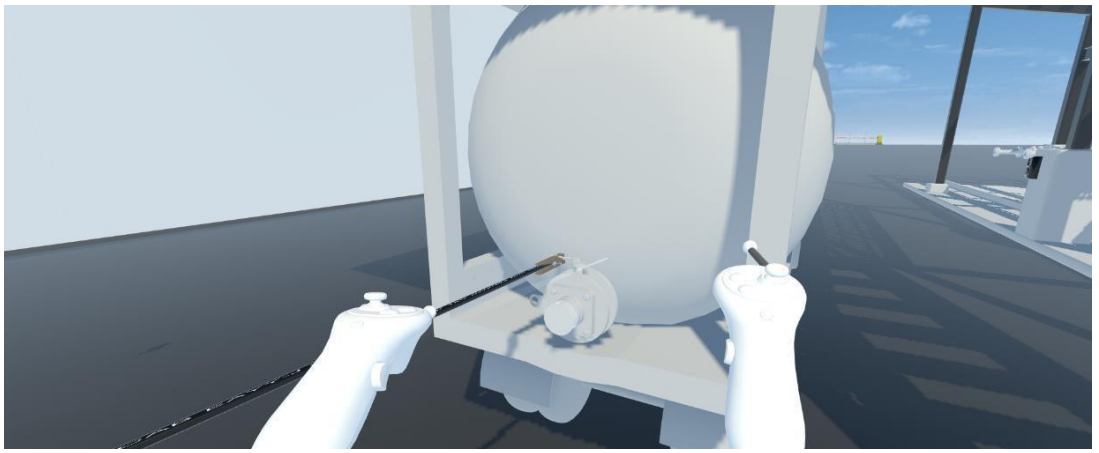


Figure 4.10 Connect Loading Hose

4.3.2.11 Simulation Complete Scene

If the user successfully connects the loading hose and earth cable with the truck, the success UI will be shown and user can choose to continue to main menu by clicking on the ‘Retry’ button or close the application by clicking on ‘Quit’ as shown in Figure 4.11.

Figure 4.11 Simulation Complete UI

4.3.2.12 Explosion Scene

If the user did not connect the earth bonding to the truck, an explosion will happen and user can choose to continue to main menu by clicking on the ‘Retry’ button or close the application by clicking on ‘Quit’ as shown in Figure 4.12 and a failure explosion UI will be shown.

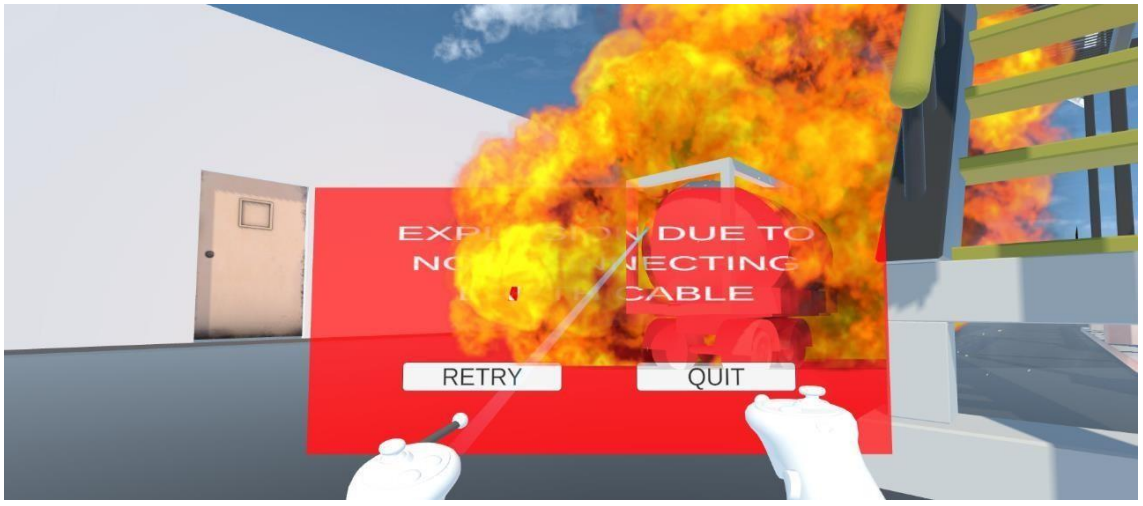


Figure 4.12 Explosion Scene

4.3.2.13 Leakage Scene

If the user did not connect the loading hose to the truck, a leakage will happen at the back of the truck where loading hose are supposedly connected and user can choose to continue to main menu by clicking on the ‘Retry’ button or close the application by clicking on ‘Quit’ as shown in Figure 4.13 and a failure leakage UI will be shown.

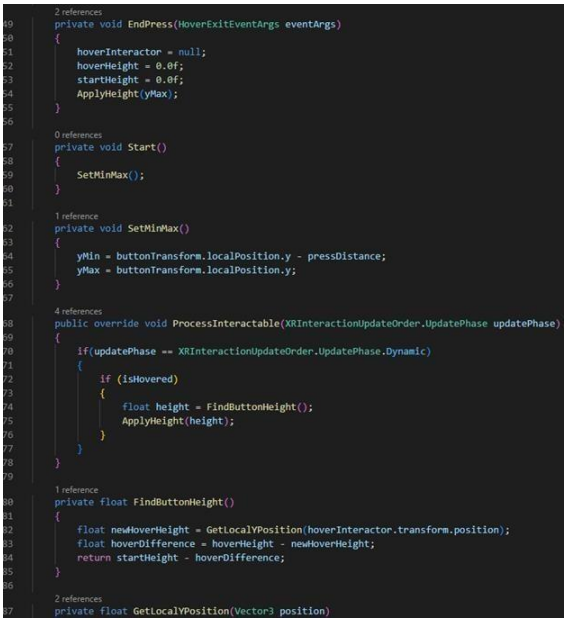
Figure 4.13 Leakage Scene

4.4 Coding

4.4.1 XR button Code

```
using UnityEngine;
using UnityEngine.Events;
using UnityEngine.XR.Interaction.Toolkit;

1 reference
public class XRButton : XRBaseInteractable
{
    [Tooltip("The transform of the visual component of the button")]
    6 references
    public Transform buttonTransform = null;

    [Tooltip("The distance the button can be pressed")]
    2 references
    public float pressDistance = 0.1f;

    // When the button is pressed
    1 reference
    public UnityEvent OnPress = new UnityEvent();

    // When the button is released
    1 reference
    public UnityEvent OnRelease = new UnityEvent();

    3 references
    private float yMin = 0.0f;
    3 references
    private float yMax = 0.0f;

    4 references
    private IXRHoverInteractor hoverInteractor = null;

    3 references
    private float hoverHeight = 0.0f;
    3 references
    private float startHeight = 0.0f;
    2 references
    private bool previousPress = false;

    5 references
    protected override void OnEnable()
    {
        base.OnEnable();
        hoverEntered.AddListener(StartPress);
        hoverExited.AddListener(EndPress);
    }

    5 references
    protected override void OnDisable()
    {
        base.OnDisable();
        hoverEntered.RemoveListener(StartPress);
```

Figure 4.14 XR button Code 1



```
    2 references
    private void EndPress(HoverExitEventArgs eventArgs)
    {
        hoverInteractor = null;
        hoverHeight = 0.0f;
        startHeight = 0.0f;
        ApplyHeight(yMax);
    }

    0 references
    private void Start()
    {
        SetMinMax();
    }

    1 reference
    private void SetMinMax()
    {
        yMin = buttonTransform.localPosition.y - pressDistance;
        yMax = buttonTransform.localPosition.y;
    }

    4 references
    public override void ProcessInteractable(XRInteractionUpdateOrder.UpdatePhase updatePhase)
    {
        if(updatePhase == XRInteractionUpdateOrder.UpdatePhase.Dynamic)
        {
            if (isHovered)
            {
                float height = FindButtonHeight();
                ApplyHeight(height);
            }
        }
    }

    1 reference
    private float FindButtonHeight()
    {
        float newHoverHeight = GetLocalYPosition(hoverInteractor.transform.position);
        float hoverDifference = hoverHeight - newHoverHeight;
        return startHeight - hoverDifference;
    }

    2 references
    private float GetLocalYPosition(Vector3 position)
```

Figure 4.15 XR button Code 2

4.4.2 Teleport Player Code

```
using UnityEngine;
using UnityEngine.XR.Interaction.Toolkit;


0 references
public class TeleportPlayer : MonoBehaviour
{
    [Tooltip("The anchor the player is teleported to")]
    3 references
    public TeleportationAnchor anchor = null;

    [Tooltip("The provider used to request the teleportation")]
    2 references
    public TeleportationProvider provider = null;

    0 references
    public void Teleport()
    {
        if(anchor && provider)
        {
            TeleportRequest request = CreateRequest();
            provider.QueueTeleportRequest(request);
        }
    }

    1 reference
    private TeleportRequest CreateRequest()
    {
        Transform anchorTransform = anchor.teleportAnchorTransform;

        TeleportRequest request = new TeleportRequest()
        {
            requestTime = Time.time,
            matchOrientation = anchor.matchOrientation,

            destinationPosition = anchorTransform.position,
            destinationRotation = anchorTransform.rotation
        };

        return request;
    }
}

```

Figure 4.16 Teleport Player Code

4.4.3 Load Scene code

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class CutsceneSwitch : MonoBehaviour
{
    private void OnEnable()
    {
        SceneManager.LoadScene("SampleScene", LoadSceneMode.Single);
    }
}
```

Figure 4.17 Load Scene code

4.4.4 Play Video Code

```
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Video;

[RequireComponent(typeof(VideoPlayer))]
0 references
public class PlayVideo : MonoBehaviour
{
    [Tooltip("Whether video should play on load")]
    1 reference
    public bool playAtStart = false;

    [Tooltip("Material used for playing the video (Uses URP/Unlit by default)")]
    4 references
    public Material videoMaterial = null;

    [Tooltip("List of video clips to pull from")]
    8 references
    public List<VideoClip> videoClips = new List<VideoClip>();

    9 references
    private VideoPlayer videoPlayer = null;
    2 references
    private MeshRenderer meshRenderer = null;

    6 references
    private int index = 0;

    0 references
    private void Awake()
    {
        meshRenderer = GetComponent<MeshRenderer>();
        videoPlayer = GetComponent<VideoPlayer>();

        if (videoClips.Count > 0)
            videoPlayer.clip = videoClips[0];
    }

    0 references
    private void OnEnable()
    {
        videoPlayer.prepareCompleted += ApplyVideoMaterial;
    }

    0 references
    private void OnDisable()
    {
        videoPlayer.prepareCompleted -= ApplyVideoMaterial;
    }
```

Figure 4.18 Play Video Code

4.4.5 Main Menu Controller code

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

0 references
public class MainMenuController : MonoBehaviour
{
    0 references
    public void StartBtn()
    {
     SceneManager.LoadScene("Intro Truck");
    }

    0 references
    public void RetryBtn()
    {
       SceneManager.LoadScene("Main Menu");
    }

    0 references
    public void Quit()
    {
     Application.Quit();
     Debug.Log("Quit");
    }
}

```

Figure 4.19 Main Menu Controller Code

4.4.6 Simulation Manager Code

```
using System.Collections;
using UnityEngine;
using UnityEngine.UI;

2 references
public class SimulationManager : MonoBehaviour
{
    4 references
    [SerializeField] private int leakageHappened;
    4 references
    [SerializeField] private int explosionHappened;
    1 reference
    [SerializeField] private int numberOfTasksToComplete;
    5 references
    [SerializeField] private int currentlyCompletedTasks = 0;

    1 reference
    public GameObject explosionGameOver;
    1 reference
    public GameObject leakageGameOver;

    1 reference
    public GameObject leakageUI;

    1 reference
    public GameObject explosionUI;

    1 reference
    public GameObject winUI;

     2 references
     public Button btn;

     0 references
     private void Start()
      {
          Button startbtn = btn.GetComponent<Button>();
          btn.onClick.AddListener(TaskOnClick);
          leakageHappened = 1;
          explosionHappened = 1;

      }

    1 reference
    public void SolveLeakage()
    {
        leakageHappened--;
        currentlyCompletedTasks++;
    }

    1 reference
```

Figure 4.20 Simulation Manager Code 1

```
1 reference
public void SolveExplosion()
{
    explosionHappened--;
    currentlyCompletedTasks++;
}

1 reference
void TaskOnClick()
{
    if (currentlyCompletedTasks >= numberOfTasksToComplete)
    {
        Debug.Log("Success");
        StartCoroutine(WaitBeforeShow3());

    }

    else if (explosionHappened >= 1)
    {
        Debug.Log("Explosion");
        explosionGameOver.SetActive(true);
        StartCoroutine(WaitBeforeShow2());
    }

    else if (leakageHappened >= 1)
    {
        Debug.Log("Leakage");
        leakageGameOver.SetActive(true);

        StartCoroutine(WaitBeforeShow());

    }

    IEnumerator WaitBeforeShow()
    {
        yield return new WaitForSeconds(3);
        leakageUI.SetActive(true);
    }

        IEnumerator WaitBeforeShow2()
    {
        yield return new WaitForSeconds(3);
        explosionUI.SetActive(true);
    }
```

Figure 4.21 Simulation Manager Code 2

```
        }

            IEnumerator WaitBeforeShow3()
        {
            yield return new WaitForSeconds(3);
            winUI.SetActive(true);
        }

    }

    1 reference
    public void Explosion()
    {
        explosionHappened ++;
        currentlyCompletedTasks--;
    }

    1 reference
    public void Leakage()
    {
        leakageHappened ++;
        currentlyCompletedTasks--;
    }
}

```

Figure 4.22 Simulation Manager Code 3

4.4.7 Toggle Canvas Code

```
using UnityEngine;

0 references
public class ToggleInterface : MonoBehaviour
{
    [Tooltip("Sets canvas starting visibility")]
    1 reference
    public bool enableOnStart = false;
    4 references
    private Canvas canvas = null;

    0 references
    private void Awake()
    {
        canvas = GetComponent<Canvas>();
    }

    0 references
    private void Start()
    {
        canvas.enabled = enableOnStart;
    }

    0 references
    public void Toggle()
    {
        bool isEnabled = !canvas.enabled;
        canvas.enabled = isEnabled;
    }
}
```

Figure 4.23 Toggle Canvas Code

4.4.8 Equipment Controller Code

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class CutsceneSwitch : MonoBehaviour
{
    private void OnEnable()
    {
        SceneManager.LoadScene("SampleScene", LoadSceneMode.Single);
    }
}

```

Figure 4.24 Equipment Controller Code

4.4.9 Explosion Manager Code

```
using UnityEngine;
using UnityEngine.XR.Interaction.Toolkit;

0 references
public class ExplosionManager : MonoBehaviour
{
    2 references
    [SerializeField] private SimulationManager sManager;
    2 references
    [SerializeField] private Transform earthSocketPiece;
    5 references
    private XRSocketInteractor earthSocket;

    0 references
    private void Awake()
    {
        earthSocket = GetComponent<XRSocketInteractor>();
    }

    0 references
    private void OnEnable()
    {
        earthSocket.selectEntered.AddListener(ObjectSnapped);
        earthSocket.selectExited.AddListener(ObjectRemoved);
    }

    0 references
    private void OnDisable()
    {
        earthSocket.selectEntered.RemoveListener(ObjectSnapped);
        earthSocket.selectExited.RemoveListener(ObjectRemoved);
    }

    2 references
    private void ObjectSnapped(SelectEnterEventArgs arg0)
    {
        var snappedcableName = arg0.interactableObject;
        if (snappedcableName.transform.name == earthSocketPiece.name)
        {
            sManager.SolveExplosion();
        }
    }

    2 references
    private void ObjectRemoved(SelectExitEventArgs arg0)
    {
        var removedcableName = arg0.interactableObject;
        if (removedcableName.transform.name == earthSocketPiece.name)
        {
            sManager.Explosion();
        }
    }
}
```

Figure 4.25 Explosion Manager Code

4.4.10 Leakage Manager Code

```
using UnityEngine;
using UnityEngine.XR.Interaction.Toolkit;


0 references
public class LeakageManager : MonoBehaviour
{
    2 references
    [SerializeField] private SimulationManager sManager;
    2 references
    [SerializeField] private Transform cableSocketPiece;
    5 references
    private XRSocketInteractor cableSocket;


    0 references
    private void Awake()
    {
        cableSocket = GetComponent<XRSocketInteractor>();
    }

    0 references
    private void OnEnable()
    {
        cableSocket.selectEntered.AddListener(ObjectSnapped);
        cableSocket.selectExited.AddListener(ObjectRemoved);
    }

    0 references
    private void OnDisable()
    {
        cableSocket.selectEntered.RemoveListener(ObjectSnapped);
        cableSocket.selectExited.RemoveListener(ObjectRemoved);
    }

    2 references
    private void ObjectSnapped(SelectEnterEventArgs arg0)
    {
        var snappedcableName = arg0.interactableObject;
        if (snappedcableName.transform.name == cableSocketPiece.name)
        {
            sManager.SolveLeakage();
        }
    }

    2 references
    private void ObjectRemoved(SelectExitEventArgs arg0)
    {
       var removedcableName = arg0.interactableObject;
        if (removedcableName.transform.name == cableSocketPiece.name)
        {
            sManager.Leakage();
        }
    }


}
```

Figure 4.26 Leakage Manager Code

4.4.11 PPE Selection Code

```
using UnityEngine;
using UnityEngine.XR.Interaction.Toolkit;

0 references
public class PPE : MonoBehaviour
{
    2 references
    [SerializeField] private EquipmentsController linkedEquipmentsController;
    2 references
    [SerializeField] private Transform CorrectPuzzlePiece;
    5 references
    private XRSocketInteractor socket;

    0 references
    private void Awake() => socket = GetComponent<XRSocketInteractor>();

    0 references
    private void OnEnable()
    {
        socket.selectEntered.AddListener(ObjectSnapped);
        socket.selectExited.AddListener(ObjectRemoved);
    }

    0 references
    private void OnDisable()
    {
        socket.selectEntered.RemoveListener(ObjectSnapped);
        socket.selectExited.RemoveListener(ObjectRemoved);
    }


    2 references
    private void ObjectSnapped(SelectEnterEventArgs arg0)
    {
        var snappedObjectName = arg0.interactableObject;
        if (snappedObjectName.transform.name == CorrectPuzzlePiece.name)
        {
            linkedEquipmentsController.CompletedPuzzleTask();
        }
    }

    2 references
    private void ObjectRemoved(SelectExitEventArgs arg0)
    {
        var removedObjectName = arg0.interactableObject;
        if (removedObjectName.transform.name == CorrectPuzzlePiece.name)
        {
            linkedEquipmentsController.PuzzlePieceRemoved();
        }
    }
}
```

Figure 4.27 PPE Selection Code

4.4.12 Equipment Controller Detection Code

```
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.Events;

1 reference
public class EquipmentsController : MonoBehaviour
{
    1 reference
    [SerializeField] private int numberOfTasksToComplete;
    3 references
    [SerializeField] private int currentlyCompletedTasks = 0;

    1 reference
    public void CompletedPuzzleTask()
    {
        currentlyCompletedTasks++;
        CheckForPuzzleCompletetion();
    }

    1 reference
    private void CheckForPuzzleCompletetion()
    {
        if(currentlyCompletedTasks >= numberOfTasksToComplete)
        {
        }
    }

    1 reference
    public void PuzzlePieceRemoved()
    {
        currentlyCompletedTasks--;
    }
}
```

Figure 4.28 Equipment Controller Detection Code

4.5 TESTING AND RESULT DISCUSSION

Load Chemical from Truck to Storage Tank Simulation Training Using Virtual Reality is developed using Unity, Microsoft Studio and Canva. In the development process, testing is a vital activity of the process since it ensures that all of functionality are free from error. The testing is conducted throughout all the development stages.

4.5.1 Functional Testing

Unit Testing and User Acceptance Testing are used to test the Load Chemical from Truck to Storage Tank Simulation Training system. Each of the testing will be discussed further below:

i) User Acceptance Testing

Load Chemical from Truck to Storage Tank Simulation Training Using Virtual Reality is being testing to the client to make sure that it functions as planned and meet the expectation of the client's criteria. The client is in charge of figuring out whether the offered system satisfies the user's needs and whether it is prepared for implementation in a genuine market. In addition, a survey of additional users was conducted, including landlords and students, to see whether the system satisfied their needs. The results of UAT shows that all the features in the VR application can function. While for testing and evaluating usability and effectiveness of the VR application, a survey using Google form is given to the users after they test the application. The survey consists of six questions where users are required to answer question 1 to question 6 by rating based on the scale strongly disagree, disagree, neutral, agree, and strongly agree.

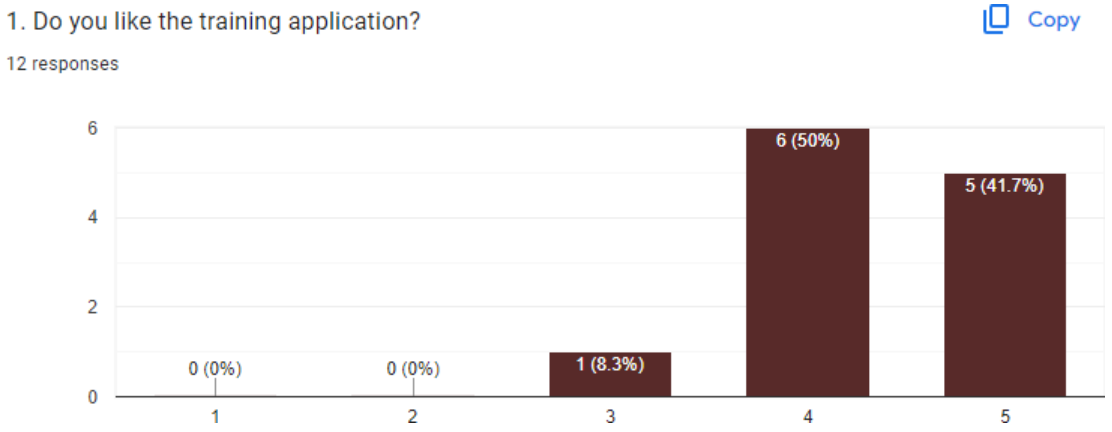


Figure 4.29 Google Form Q1

Based on the survey conducted, 41.7% strongly agree that they like the VR training application. 50% agree that they like it whereas the other 8.3% feels neutral about this application.

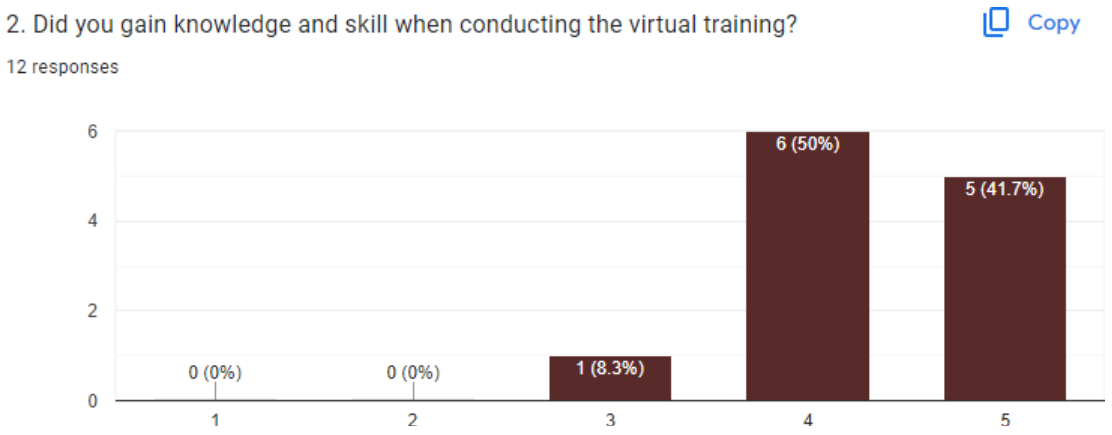


Figure 4.30 Google Form Q2

For the second question, 41.7% strongly agree and 50% half agree while 8.3% feels neutral that they can gainknowledge and skills when conducting the training.

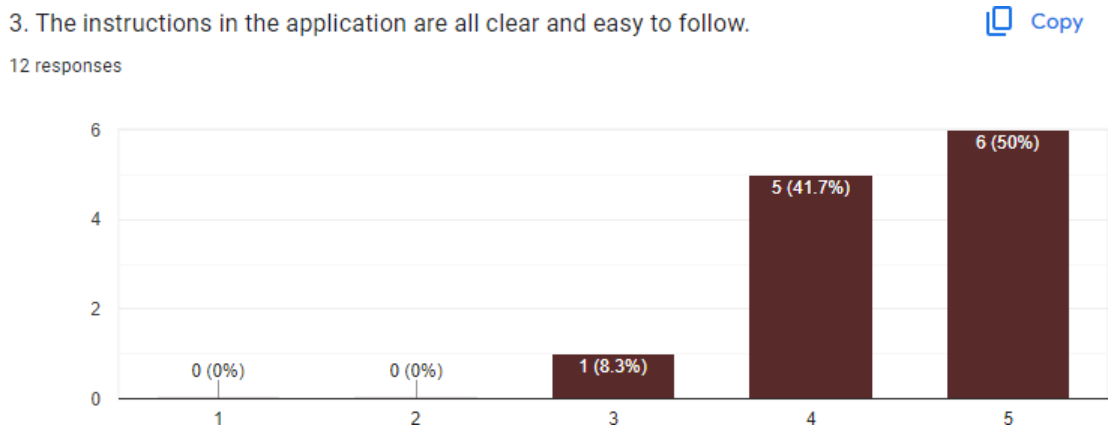


Figure 4.31 Google Form Q3

Next, 50% strongly agree that the instructions in the application is clear and easytofollow. 41.7% agree whereas the other 8.3% feels neutral.

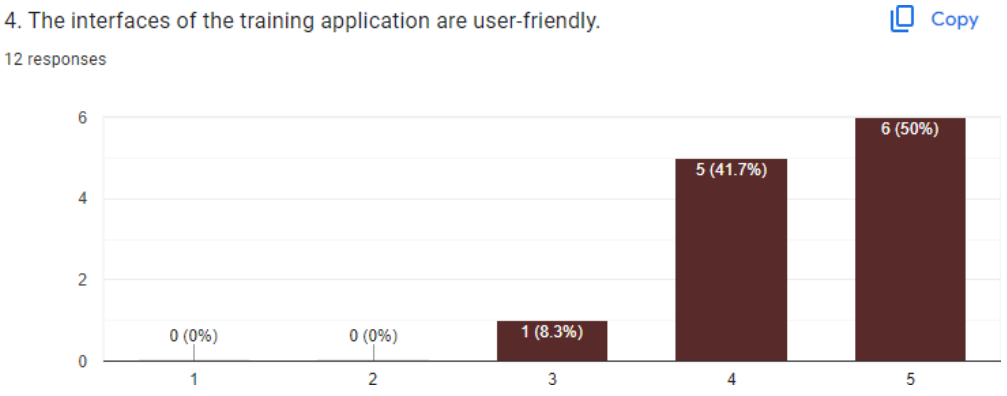


Figure 4.32 Google Form Q4

For the interface of the application, 50% strongly agree that they are user-friendly. 41.7% agree whereas only 8.3% person feels neutral.

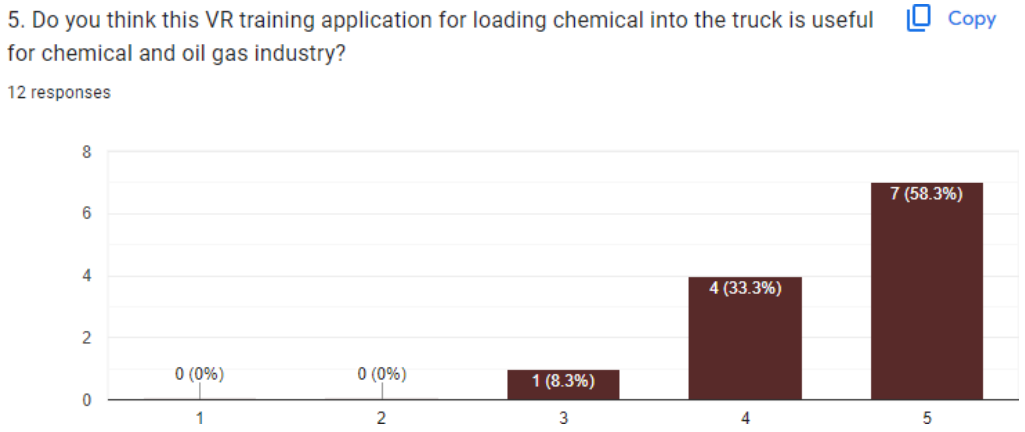


Figure 4.33 Google Form Q5

58.3% agree that this VR training application would be useful in oil and gasindustry. 33.3 % agree whereas only 8.3% person feels neutral.

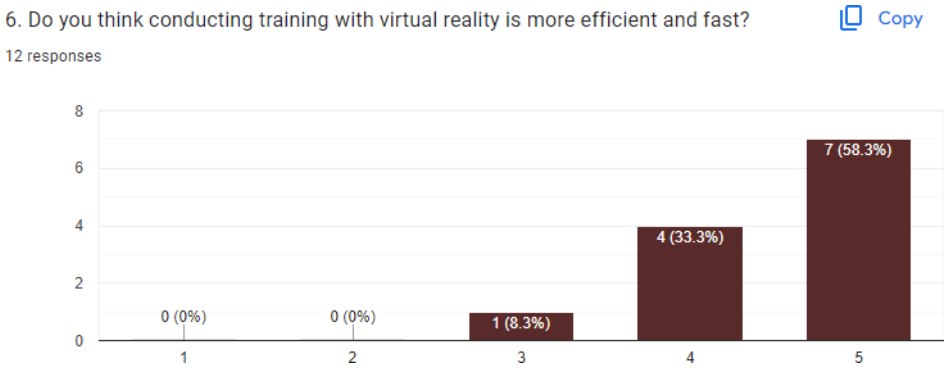


Figure 4.34 Google Form Q6

Lastly, 58.3% strongly agree and 33.3% agree while 8.3% feels neutral on conducting training virtually is faster and more efficient.

User Acceptance Testing form

No	Event	Status: Pass(P)/Fail(F)
Main Menu		
1	Able to click “Start button”	P
2	Able to click “Quit” button	P
Truck Enters		

1	Able cut scene to play	P
2	Able to move to next scene after cut scene finishes	P
PPE Selection		
1	Able to grab objects in the scene	P
2	Able to drop objects in the socket interactors	P
3	Able to walk around the area.	P
4	Able to click on list icon to readthe bill of lading.	P
5	Able to click on instructions icon to read the instructions.	P
6	Able to display message that indicates player can move to the next scene.	P
Simulation (Main function)		
1	Able to click on bill icon to readbill of lading information.	P
2	Able to click on instruction icon to read the steps for the training.	P
3	Able to walk around the area.	P
4	Able to grab objects in the scene.	P
5	Able to drop objects in the socket interactors.	P

6	Able to read storage tank information by clicking on a board 3D model.	P
7	Able to click the buttons in the scene.	P
8	Able to display instructions on the screen.	P
9	Able to pop up congratulation message if steps are completed by the user and training is a success.	P
10	Able to click “Retry” to restart the training.	P
11	Able to click “Quit” to exit the VR training application.	P
Simulation (Explosion)		
1	Able to trigger explosion when earth-bonding cable is not connected after starting process of unloading chemical.	P
2	Able to pop up failure message due to explosion.	P
3	Able to click “Retry” to restart the training.	P
4	Able to click “Quit” to exit the VR training application.	P
Simulation (Leaking from truck hose)		
1	Able to trigger leakage from hose when hose is not properly connected to the truck after starting process of unloading chemical.	F

2	Able to pop up failure message due to leakage from truck hose.	F
3	Able to click “Retry” to restart the training.	F
4	Able to click “Quit” to exit the VR training application.	F
Simulation (Leaking from storage tank)		
1	Able to trigger leakage from storage tank when the amount of chemical chosen is wrong after starting process of unloading chemical.	F
2	Able to pop up failure message due to leakage from storage tank.	P
3	Able to click “Retry” to restart the training.	F
4	Able to click “Quit” to exit the VR training application.	F

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

In order to accomplish the goals and address the issues that had been previously stated, Chapter 5 will explain the overview of the creation of a Load Chemical from Truck to Storage Tank using VR application for workers in the chemical sector. Operators formerly relied on static resources, such as instruction books, for the steps and processes they followed. The lengthy and dull thick manuals could be a turnoff for production workers. This causes workers to skip steps and not read the instructions even when they are risk-unaware. Since these feature multimedia components like animations, audios, and pictures, this VR application may be used as a tool to grab workers' interest in and inspire them to learn about the process of loading chemicals. Unity and Microsoft Visual Code were the two programs utilized to create this application.

In Chapter 1, the objectives are to investigate the characteristics and functions of VR training apps based on those already in use for chemical safety training. This goal has been attained in Chapter 2, which compares and analyses three existing VR applications based on chemical safety.

The next goal is to design and create a VR training application prototype for the activity of loading chemicals from trucks into storage tanks in the chemical industry. This has been done in Chapter 3, which goes into greater depth on the project's development utilizing the ADDIE technique, which is straightforward to apply, adaptable to changing requirements, and able to go back to prior phases.

In Chapter 4 of the user acceptability testing form, the functioning of the created VR training application for chemical loading activities from truck to storage

tank has been assessed. Thus, chapter 4 tests and achieves the established application functions. Several additional persons assessed the VR application to assess its effectiveness and usefulness. This application obtains positive comments, according to the evaluation method.

5.2 RESEARCH CONSTRAINTS

There are a few constraints that been faced during the development of the project such as:

i) Time

The development of the project starts on March 2022 and is expected to be completed by May 2023. Because of that, there are only few scenarios that can be applied in this project.

ii) Coding

There are sometimes where error(s) occur in the script. When there are error(s), the game application would not be able to test or run. The error(s) need to be solved in order to run the game application.

5.3 FUTURE WORK

In the future, with a better knowledge and better time management, this application can grow even better as there are several improvements that can be made to this project such as:

I. Design the background to make it more realistic and similar to an industrial site.

II. Add training with scores at the end of training to test user's skill within limited time.

III. Add more challenging scenario and scenes for the user to adapt with disasters that may happen during actual works.

IV. Design the user interface to looks more eye catchy and complex.

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APPENDIX A
APPLICATION TESTING

Loading Chemical from Truck to Storage Tank Simulation Training using VR

ammarozali@gmail.com Switch account

Not shared

* Indicates required question

1. Do you like the training application? *

	1	2	3	4	5	
Very Bad	○	○	○	○	○	Very Good

2. Did you gain knowledge and skill when conducting the virtual training? *

	1	2	3	4	5	
I didn't any knowledge or skill	○	○	○	○	○	I learned a lot knowledge and skill

3. The instructions in the application are all clear and easy to follow. *

	1	2	3	4	5	
Very Bad	○	○	○	○	○	Very Good

4. The interfaces of the training application are user-friendly. *

	1	2	3	4	5	
Not user-friendly	○	○	○	○	○	Very user-friendly

5. Do you think this VR training application for loading chemical into the truck is useful for chemical and oil gas industry? *

	1	2	3	4	5	
I didn't agree	○	○	○	○	○	I agree

6. Do you think conducting training with virtual reality is more efficient and fast? *

	1	2	3	4	5	
I didn't agree	○	○	○	○	○	I agree