Faculty of Computer Science and Information Technology

OBJECTIVE TERMINAL: 3D MULTIPLAYER COLLABORATIVE LEARNING GAME

IMRAN HARRIZ BIN MADZALAN

Bachelor of Software Engineering with Honours

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This project is submitted in partial fulfilment of
the requirements of Bachelor of Computer Science with Honours
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DECLARATION

I, Imran Harriz bin Madzalan hereby declare that this thesis titled “Objective Terminal – 3D Multiplayer Collaborative Learning Game” is my original work. I have not copied from other student’s work or from any other sources except from quotations and citations which have been duly acknowledged.

IMRAN HARRIZ BIN MADZALAN) 28th July 2025

Faculty of Computer Science and Information Technology
Universiti Malaysia Sarawak

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Special thanks goes to my classmates and friends for making the difficult moments managable and the good times memorable. Their encouragement, camaraderie and shared experiences made this journey, from the beginning to the end of it, a remarkable one.

ABSTRACT

The KSSM Chemistry subject is the most challenging subject in the SPM science stream, indicated by high failure rates in Sijil Pelajaran Malaysia (SPM), which educators have expressed desires to alternative methods to teaching Chemistry. Implementation of collaborative learning techniques in a Chemistry class has shown to have significant results in helping tertiary students learn Chemistry topics. Thus, this project aims to study the efficacy of conducting collaborative learning sessions though an immersive 3D digital game in helping Form 4 students learn the KSSM Form 4 Chemistry Subject. The SCRUM Methodology has been used to develop the 3D collaborative puzzle game. Interviews and surveys were conducted to Chemistry teachers and Form 4 students respectively to determine the suitable Chemistry topic to be included in the 3D collaborative game. Next, the game's features and Product Backlog were outlined to list down the basic requirements to develop the game. The game's mechanics were also explained in depth and were developed and implemented in short iterations called "sprints". Two Form 4 classes were chosen for testing of the project. Each class were then divided in two groups, namely the experimental and control groups. Both groups were given a pre-test and post-test, and the control group were given reading material whereas the experimental group played the game. The study yielded that the experimental group achieved significant improvements over the control group. The mean difference between the pre-test and post-test of the control group valued at 0.5, whereas the experimental group had a mean difference of 2.5. Using the paired samples t-test, the control group had a p-value of 0.1075, whereas the experimental group achieved a p-value 0.03163. This indicates a positive effect of Objective Terminal in teaching Form 4 students chemistry over conventional studying methods.

ABSTRAK

Mata pelajaran Kimia KSSM merupakan mata pelajaran yang paling mencabar dalam aliran sains SPM, ditunjukkan oleh kadar kegagalan yang tinggi dalam Sijil Pelajaran Malaysia (SPM), yang mana pendidik telah menyatakan hasrat kepada kaedah alternatif untuk mengajar Kimia. Pelaksanaan teknik pembelajaran kolaboratif dalam kelas Kimia telah menunjukkan hasil yang ketara dalam membantu pelajar pengajian tinggi mempelajari topik Kimia. Justeru, projek ini bertujuan untuk mengkaji keberkesanan menjalankan sesi pembelajaran kolaboratif melalui permainan digital 3D yang mengasyikkan dalam membantu pelajar Tingkatan 4 mempelajari Mata Pelajaran Kimia KSSM Tingkatan 4. Metodologi SCRUM telah digunakan untuk membangunkan permainan teka-teki kolaboratif 3D. Temu bual dan tinjauan telah dijalankan kepada guru Kimia dan pelajar Tingkatan 4 masing-masing untuk menentukan topik Kimia yang sesuai. Seterusnya, ciri permainan dan Product Backlog telah digariskan untuk menyenaraikan keperluan asas untuk membangunkan permainan. Mekanik permainan juga diterangkan secara mendalam dan akan dibangunkan lelaran pendek yang dipanggil "sprint". Hasil yang dijangkakan ialah permainan berbilang pemain 3D yang boleh menunjukkan keberkesanan menjalankan sesi pembelajaran kolaboratif melalui permainan digital 3D yang mengasyikkan. Dua kelas Tingkatan 4 diuji, dibahagikan kepada kumpulan eksperimen (bermain permainan) dan kumpulan kawalan (menggunakan bahan bacaan). Kedua-dua kumpulan menjalani pre-test dan post-test Hasil kajian menunjukkan kumpulan eksperimen mencatat peningkatan min 2.5 berbanding 0.5 untuk kumpulan kawalan; p-value kumpulan eksperimen ialah 0.03163 (signifikan), manakala kumpulan kawalan 0.1075 (tidak signifikan). Ini membuktikan permainan Terminal Objektif memberi impak positif terhadap pembelajaran Kimia pelajar Tingkatan 4.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Today, it is not uncommon to find that many students play digital games. According to Ng (2023), the highest proportion of online game players in Malaysia were individuals aged between 16 and 24 years old. These digital games offer an interactive environment, accompanied by audiovisual feedback mechanisms like points, leaderboards and achievements. In turn, these feedback mechanisms motivates these players to engage in such a manner that requires them to focus deeply, as it fosters confidence in their abilities, and this heightened sense of proficiency might enhance their appreciation for the content or activity (Medina, 2005).

Chemistry, one of the most challenging subjects in Malaysia's science curriculum, often leads to high failure rates in the *Sijil Pelajaran Malaysia* (SPM) exams (*Kementerian Pendidikan Lembaga Peperiksaan*, 2024). Recognizing this challenge, Chemistry educators in Malaysia have expressed interest in innovating their teaching methods to improve student learning outcomes (Veerasinghan et al., 2023). Given the complexity of Chemistry concepts, chemical elements, and reactions, traditional classroom settings may struggle to effectively convey this information. Therefore, incorporating learning techniques like game-based learning and collaborative learning approach could offer a more engaging and effective approach to teaching chemistry.

The concept of "collaborative learning" encompasses a range of educational strategies that involve collective intellectual work by students, either individually or in conjunction with their teachers. This approach emphasizes teamwork and shared learning experiences among participants. (Smith and MacGregor, 1992). For chemistry education in particular, students that participate in active learning techniques such as collaborative learning and game-based learning perform better compared to those passively listening to lectures.(Byusa et al., 2022).

Digital games can be applied for educational purposes. This genre of digital game is called an educational game, and is divided into two types: gamification and game-based learning. Gamification is applying game elements in a non-gaming context, whereas game based learning (GBL) allows the user to learn a specific topic with the game as a central aspect of it (Plass et. al., 2015). Incorporating game-based learning in education not only enhances students' comprehension of subjects but also boosts their interest and engagement (da Silva Júnior, 2021).

The SCRUM methodology will be used as the project's software development methodology. This initially project proposed to use Unreal Engine as the game engine, but had to switch to the Unity game engine due to performance considerations. The game will be developed in a 3D virtual world environment, allowing players to collaboratively prevent space ships from exploding by answering MCQ via terminals. Testing will be done on Form 4 students at a chosen secondary school.

1.2 Problem Statement

Many Form 4 and Form 5 students often have difficulty studying for exams particularly for the Chemistry subject. Chemistry is a subject taught in the *Kurikulum Standard Sekolah Menengah* (KSSM) to students in Form 4 and 5 in the Science Stream, a subject that has the highest failure rate SPM candidates taking the science stream, at 36%

(Kementerian Pendidikan Lembaga Peperiksaan, 2024). It is a hard subject for students to learn and not an easy one to teach.

One way to solve this problem is by collaborative learning, where a group of students learn, interact and share solutions with each other. However, the modules that are used to facilitate collaborative learning are limited to face-to-face modules. Furthermore, online solutions are rudimentary, and do not provide the same level of engagement offline. As such, this solution is not useful outside the classroom.

1.3 Scope

The target demographic of this project and study sample are Form 4 students who are taking the KSSM Chemistry subject as part of their academic curriculum. Form 5 Students were excluded from this study, as the research guidelines from Kementerian Pendidikan Malaysia (2020) prohibits the collection of data from Form 5 Students.

1.4 Aim and Objectives

This project aims to study the effectiveness of conducting Collaborative Learning sessions through an immersive 3D game environment. The objectives of this project are as following:

1. To design an engaging learning game focusing on the Form 4 KSSM Chemistry subject.
2. To develop a 3D multiplayer game that promotes collaborative learning by answering puzzles related to the Chemistry subject.
3. To evaluate the effectiveness of the game in regards to helping Form 4 students to study the Chemistry subject.

1.5 Brief Methodology

Figure 1.1: SCRUM Methodology(Nurjaman et al., 2024b)

The software development methodology used for the project is the SCRUM development methodology. SCRUM is the most commonly used methodology for game development due to being iterative and requirements that may change during development (Palka, 2023). The methodology prioritizes developing working software in short cycles, known as sprints, typically lasting one (1) to four (4) weeks. These Sprints have 4 phases, namely Sprint Planning, Implementation, Sprint Review, and Sprint Retrospective.

The first phase in a Sprint is the Sprint Planning phase. It is the initial phase where the user stories are gathered and put into a Product Goal. These user stories are general feature requests from players and in this project are gathered from students and teachers form questionnaires and interviews. Additionally, the game features to be developed during the Sprint are selected from the Product Goal, and put into a Sprint Backlog.

The second phase is the Implementation phase. This phase focuses on the development of the game according to the Sprint Backlog. The third phase is the Sprint Review phase. In this phase, the work completed during the Sprint will be assessed. Depending on the assessment, the feature will be marked “Done”, or returned to the Product Backlog for more work. The final phase is the Sprint Retrospective phase. This phase is where what happened well and what went wrong in the Sprint is identified for improvements in future Sprints.

Once every game feature in the Product Goal is marked “Done” the game can be defined as “Done”. The product is released to the players and the pre-test and post-tests are conducted and analysis of the effectiveness of conducting collaborative learning sessions in immersive 3D is also conducted.

1.6 Significance of Project

The project will further aid into deeper understanding of the effects of conducting Collaborative Learning sessions through immersive 3D games for Form 4 students.

1.7 Project Schedule

The project is to be completed within nine months and is split into two phases: FYP 1 and FYP 2. Each phase consists of about 14 weeks, about the length of a semester. The first phase, FYP 1 will be conducted from 7th October 2024 to 12th January 2025. The second phase, FYP 2 will be conducted from on the second semester from 17th March 2025 to 29th June 2025. A Gantt Chart for FYP 1 and FYP 2 is attached on Appendix A and Appendix B respectively.

1.8 Project Outcome

The outcome of the project is a 3D Multiplayer Collaborative Learning Game called Objective Terminal, a game about answering Multiple Choice Questions related to the Form 4

Chemistry subject. Additionally, an efficacy report of the multiplayer collaborative learning game to help students to study the subject is also included.

1.9 Summary

This chapter provides a short description of the project's introduction, problem statement, scope, aim and objectives, methodology, significance schedule and project outcome. The problem statement states that Form 4 and Form 5 students in Malaysia struggle with Chemistry, a challenging subject with a high failure rate in SPM exams, and collaborative learning solutions are limited to face-to-face interactions and lack engaging online alternatives. Hence, this project aims to study the effectiveness of conducting Collaborative Learning sessions through an immersive 3D game environment. This project uses the SCRUM methodology to design, develop and review the 3D collaborative game developed for the chosen Chemistry topic.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This literature review aims to explore the various works and applications of collaborative learning using digital games. In this chapter, works similar to the project project as well as similar games will be reviewed.

Collaborative learning is an educational approach that involves students working together in small groups or pairs to achieve a common learning goal. This method emphasizes cooperation, communication, and interdependence among learners as they share knowledge, skills, and resources to complete tasks or solve problems (Barkley, Cross, and Major, 2014). Collaborative learning can also be described as a form of active learning technique, where students engage in activities that require more involvement with the subject matter, group work, and discussions among themselves (Prince and Felder, 2006).

The next section of this chapter will review works related to the proposed project. In the third section, games related to the proposed project will be reviewed. After that, comparisons of the reviewed works and the proposed project will be made. This section has two (2) sub-sections, with the first drawing comparisons of the proposed project and related works, and the second drawing comparisons of the game with the proposed game. Each sub-section has a table that highlights major differences.

2.2 Review of Related Works

This section reviews existing research that have been done with using digital games to teach Chemistry via collaborative learning. The reviewed works will be analysed based on the aim of the research, targetted age group, focused chemistry topics, gameplay genre, method of evaluation and overall outcome of the project.

2.2.1 Orbital Battleship: A Multiplayer Guessing Game in Immersive Virtual Reality

Rychkova et al. (2020) developed a Multiplayer Virtual Reality (VR) game motivated by the positive results of visualising chemical molecules in VR, but there was insufficient studies regarding electron configurations of atoms. Prior to this, the researchers had developed a pen-and-paper version with a similar name, and goals. Hence, the researchers sought to improve upon the pen-and-paper version and develop a VR version. The study was conducted on first-year undergraduate students where they played a VR game called Orbital Battleship VR. In the game, two players are placed in a VR environment as shown in Figure 2.1. The players are to guess each other's chemical element by guessing their opponent's electron diagram as shown in Figure 2.3. The first player to guess the chemical element is regarded as the winner.

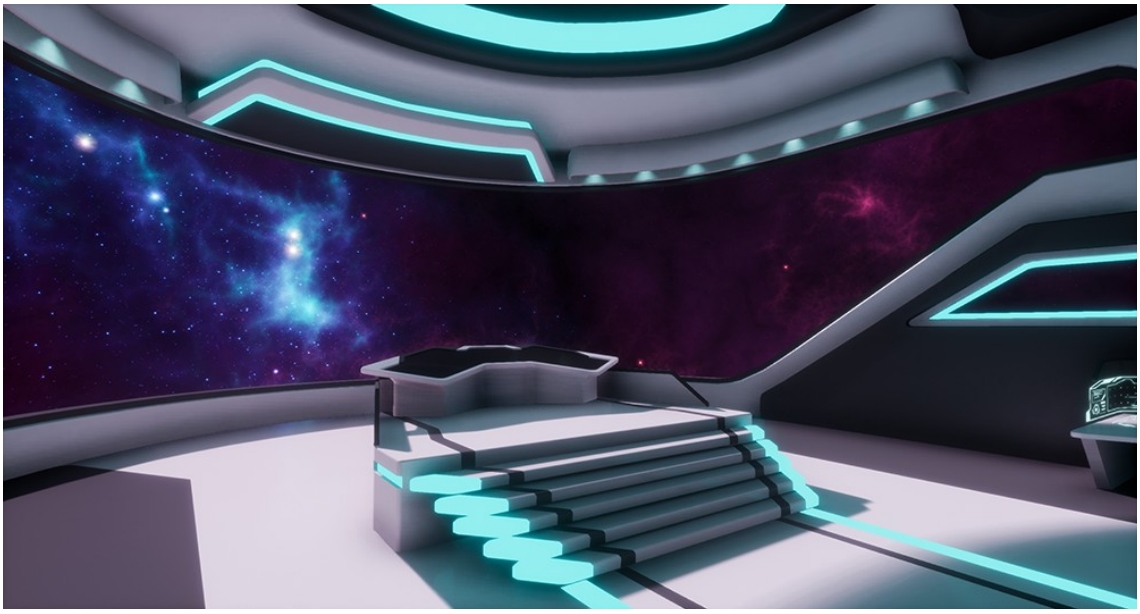

Figure 2.1: The VR Control room

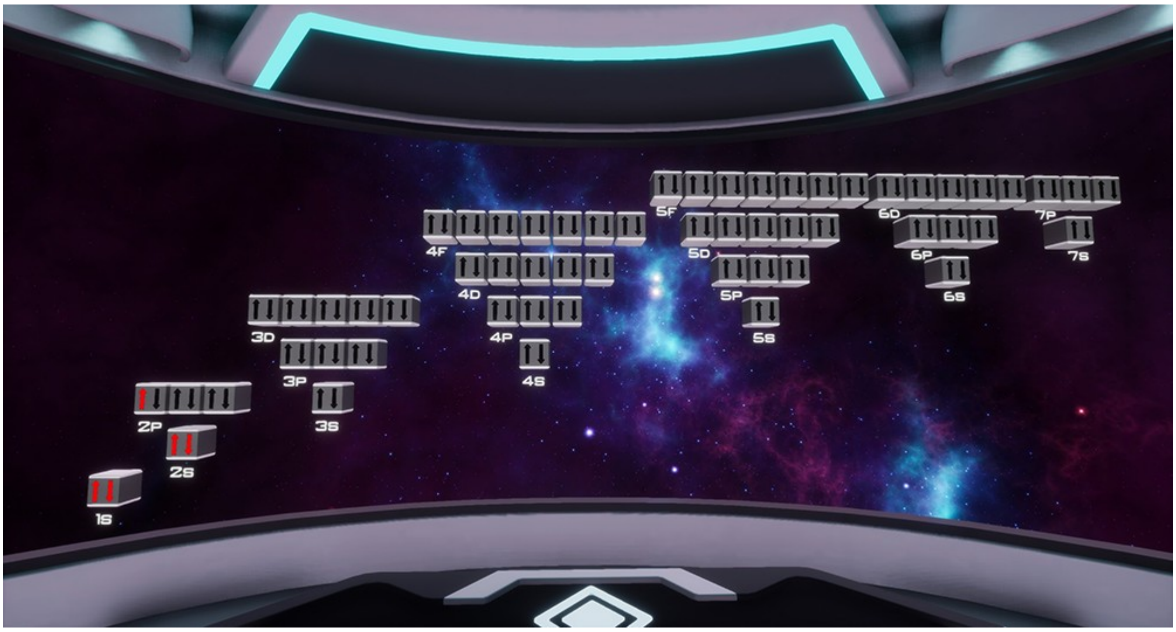

Figure 2.2: The Orbital Diagram

The research was conducted by having eight (8) students play the VR game, and another 10 students play the traditional pen-and paper version. Every student completed a pre-test that required them to write electron configurations for seven elements and create the corresponding orbital diagram. Then, each group participated in their VR or non-VR sessions, after which they performed a post-test with a new set of chemical elements.

Results of the experiment reveal that most participants, seven (7) from the VR session and eight (8) from the pen-and-paper version, performed better on the post-test compared to the pre-test. However, two (2) students had performed lower in the post-test and one student showed no difference between the two tests (by achieving the highest score). Four (4) students achieved the maximum score in the post-test. Analysis between the pre-tests and post tests showed that on average, the students that engaged with the VR version of Orbital Battleship demonstrated higher improvements compared to the students that used the pen-and-paper version. Overall, Rychkova et al. (2020) concluded by stating that the small sample size of 18 students could be a possible limitation.

2.2.2 Exploring the Use of an Avatar-Based Online Platform to Facilitate Social Interaction in Laboratory Sessions

Pang et al. (2023) conducted research on whether using avatars in a 2D game environment could foster social interaction in a chemistry laboratory session. The research was done in response to the COVID-19 pandemic, when students were barred from conducting chemical laboratory experiments physically. The selected participants for the study were third year undergraduate students. The work utilizes Gather, an online conferencing tool that incorporates multiplayer gaming elements that allows players to create custom 2D virtual worlds as well as customize their in-game avatar. A chemistry-themed escape room virtual world was created, allowing three or four players in an escape room. Figure 2.3. shows the lobby of the escape rooms and Figure 2.4. shows an example escape room created for the paper.

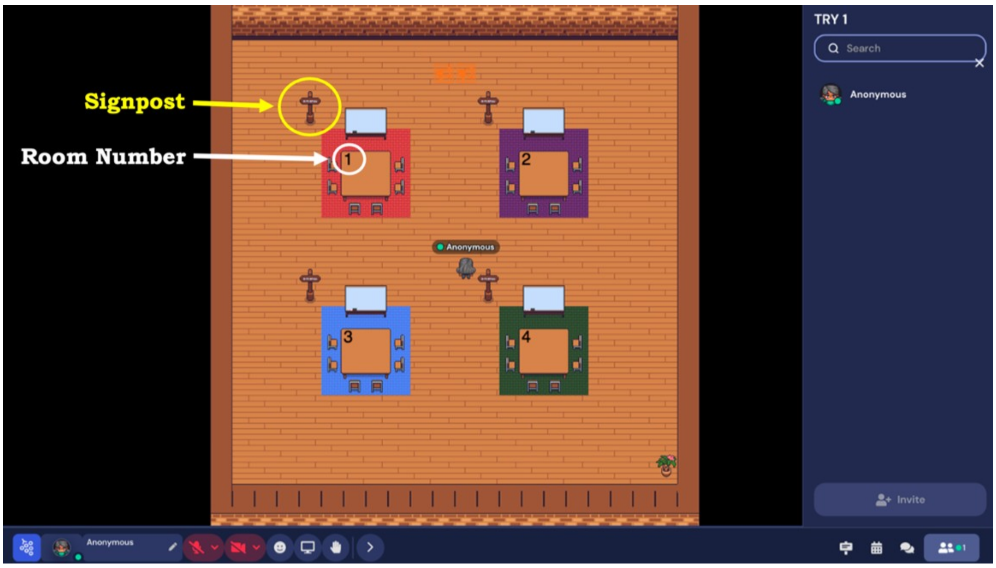

Figure 2.3: Lobby of the online escape room created in Gather

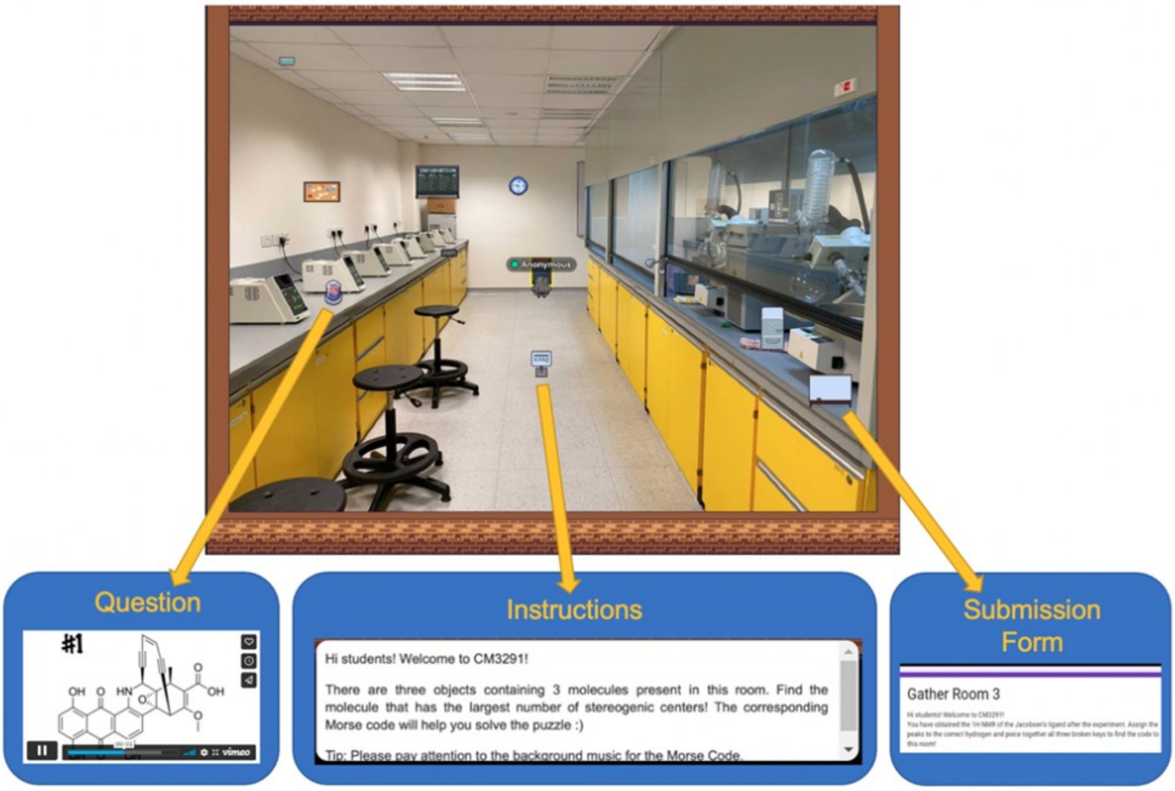

Figure 2.4: An example puzzle room showing the instructions, question and submission form the players can interact with.

The works reviewed in the paper had shown that Gather has improved online learning due to its interactive game elements. Although Gather has been explored in various educational fields, including foreign language education, which requires high student interaction akin to chemistry laboratory sessions, no studies had applied Gather to chemistry laboratory classes. Pang et al. (2023) aimed to utilize Gather in an escape room setting to determine if it fosters social interaction similarly to the reviewed studies.

26 students had participated in the online escape room activity. Before playing the escape room, the players are given some time to familiarise themselves with their group members, and the features of Gather, to reduce their anxiety. After that, the players are

assigned into a group of three to four, where the players are to complete the escape room activity in under 15 minutes. Upon completing the escape room, the players are required to submit their answer via a Google Form. After that, the participants moved to another escape room to complete the session. A survey was given to the students after the sessions are finished. The survey has twelve questions, four open-ended questions and another eight questions using the five-point Likert scale.

Analysis of the results gathered from the survey showed that students felt calmer when using Gather compared to similar platforms such as Zoom, Google Meet and Webex. This may stem from reduced self-esteem and anxiety due to the use of avatars, and the use of nicknames allowing anonymity. Next, the students were also more actively interacting with each other, and more willing to participate in new groups. Lastly, the students found completing activities in Gather more interesting than traditional practice questions. This may be due to the relaxed environment provided by gather, as indicated by the open-ended responses. The game-based learning approach appears to have encouraged interaction and reduced fear of making mistakes in a less formal atmosphere.

Pang et al. (2023) stated that while Gather can be used to teach chemistry laboratory content, it is better used as an alternative as one student preferred to have laboratory sessions face-to-face. As such, it may not be a better choice since COVID-19 restrictions have been lifted. Additionally, Gather did not support virtual backgrounds, which might be problematic for students from diverse socioeconomic backgrounds who may not have a personal space for webcam use. Gather also does not allow for custom objects like themed photos or real-life objects, restricting users to pre-installed elements on Gather for interaction.

2.2.3 The Online Version of *CHEMCompete-II*: An Organic Chemistry Card Game to Differentiate Between Substitution and Elimination Reactions of Alcohols

Lam et al. (2024) developed an online card game guided by Flow Theory. The game was developed to teach substitution and elimination reactions of alcohols to first year undergraduate students. Prior to the study, CHEMCompete-II was a physical card game developed by the same authors, with the same goal. However, the COVID-19 pandemic made it impossible for students to play the game. So the researchers saw a need for the game to be converted into an online platform. The study aims to compare the effectiveness in improving student's comprehension of the chemical reactions to the physical version.

As described by Lam et al. (2024), the online version of CHEMCompete-II was designed to present organic chemistry concepts in a creative game format to foster student engagement. Educational games can increase student motivation and enthusiasm for learning and flow theory, postulated by Mihaly Csikszentmihalyi, relates to engagement and motivation. Individuals cam reach a mental state of flow when fully involved in a task or activity, perceiving the task as intrinsically rewarding and continuing to pursue it due to their desire to do so (Csikszentmihalyi, 1975). To help students reach this state of flow when playing CHEMCompete-II, the goals of the game were clearly outlined student progress was carefully monitored during gameplay, and an immediate feedback feature was incorporated to inform students whether their selected reaction type and product cards were correct.

33 first year undergraduate students participated in the study. The students are then divided into groups of four to six, and placed into breakout rooms. Each room was led by a team leader, either a course instructor or a Supplemental Instructor. The team leaders presented the game to the students by sharing their screens. Students took turns completing

chemical reactions with their team leaders for approximately 1 hour and 30 minutes. The primary goal for each team was to collectively and successfully complete five reactions.

Pre- and post-gameplay survey were developed using Google Forms to collect and assess students' understanding of substitution and eliminations of alcohols, as well as perceptions of the game. The responses were based on a five-point Likert scale, ranging from "Strongly Agree" to "Strongly Disagree". The post-gameplay survey included spaces for students to express their opinions and provide feedback for game improvement. The pre-tests and post-tests were identical quizzes containing 5 questions, each require the student to predict reaction products, identify the reaction type, and select the appropriate mechanisms.

Analysis of the results indicated a significant improvement in quiz scores after gameplay, with an average increase of 190% among students. All statistical analysis were done using Rstudio. To assess the equality of means, t-tests were conducted. Additionally, Bhapkar ($\chi2$) tests were employed to evaluate the agreement between raters regarding the survey count data. The positive effects were widespread, bar for one student experiencing enhanced performance on their post-gameplay quiz (the exception likely improved, but their submission was incomplete). Post-gameplay questionnaires revealed that students strongly agreed that the card game made learning eliminations and substitutions more enjoyable. The students also enjoyed working in groups to play the game, and would recommend it to others. Comments from the participants include praise for the game's simplicity, effectiveness, and ease of use.

The online version of CHEMCompete-II resulted in significant improvements in quiz scores after gameplay. Additionally, an analysis of the survey data revealed a general shift towards higher confidence ratings post-gameplay. These findings collectively suggest that the online version of CHEMCompete-II is an effective tool for understanding substitution and elimination reaction of alcohols.

Lam et al. (2024) concluded the paper by detailing several limitations of the study. Firstly, a control group for comparison of academic performance was not included, as all participants played the online version of CHEMCompete-II and completed pre- and post-gameplay quizzes and surveys. Secondly, the sample size was small which can give bias to the results. Overall, Lam et al. (2024) concluded by highlighting the importance of developing games in multiple formats to accommodate diverse learning environments.

2.2.4 FemQuest – An Interactive Multiplayer Game to Engage Girls in Programming

Holly et al. (2024) developed a multiplayer game to teach young women programming. The study aimed to understand the engagement of women during a programming workshop utilizing a story based multiplayer game, and to understand the girls' cognitive workload while playing and solving programming activities. 235 participants were involved in the research, but only a subset of 20 participants were chosen for the cognitive workload objective. The game, called FemQuest, requires the players to work together to rescue a village that has been devasted by a catastrophe, by answering programming questions. Figure 2.6 shows the user interface of the 3D game and Figure 2.6 shows the programming view of the game.

Figure 2.5: User Interface of FemQuest. (A) Menu, (B) Inventory Bar, (C) Mini-Map, (D) Move- Controls, (E) Jump

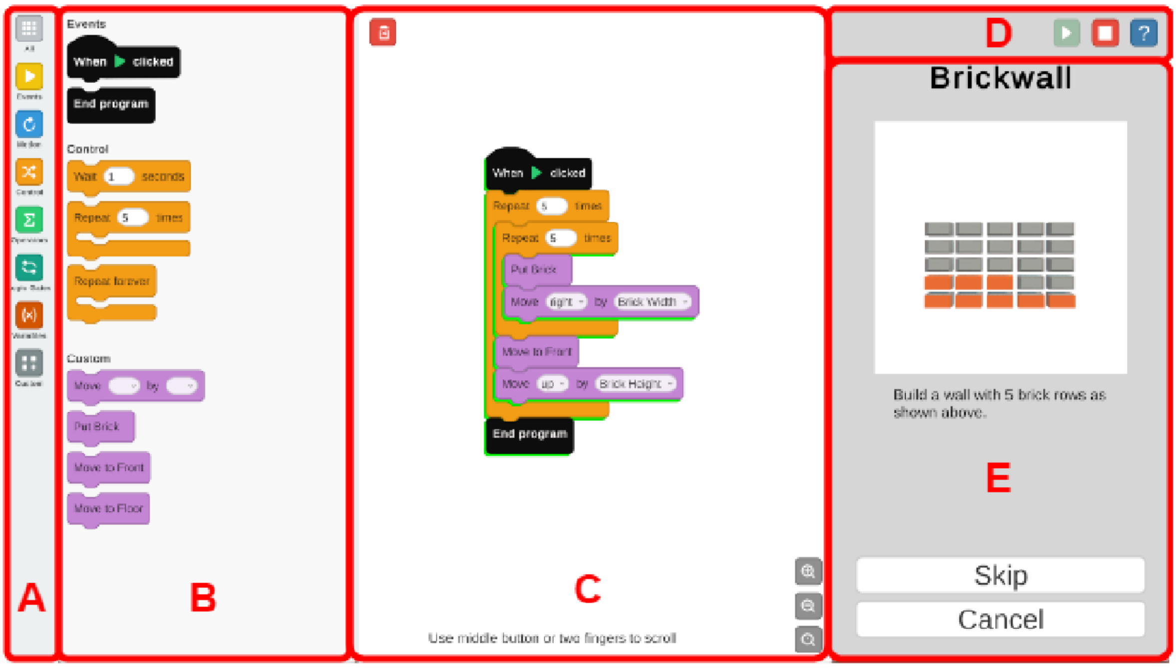

Figure 2.6: Programming View: (A): Block Categories, (B) Blocks, (C) Programming Area, (D) Execution Bar, (E) Quest View

The researchers had previously examined methods to motivate and engage students in STEM education, particularly using game-based learning approaches with chess puzzles in a virtual environment, which seemed to foster student's interest in computer science concepts. Women and girls are often less interested in Computer Science compared to men, and even those who are interested in the subject are less like likely to pursue it as a career. Thus, for Holly et al. (2024) were motivated to do the study with game aspects that appeal to women the most, like a meaningful story, non-violent and non-competitive, as well as social features.

235 girls aged 15 to 25 participated in the workshop evaluation. The researchers performed 40 workshops, which are divided in three stages. Initially, the workshop facilitator provided a brief overview of the overall process, game narrative, and various tasks. Following this introduction, participants were split into groups of 4-6, and are required to play the game for three hours with the goal of completing at least one level. The participants were accompanied by the workshop leader in case the group stumbles into any problems. After that, the participants are given a feedback survey using a 5-point Likert scale to assess their satisfaction and feedback.

Of the 235 participants in the workshops, 20 were chosen for the engagement evaluation group. In the initial stage of the workshop, the participants were given a questionnaire. During the gameplay stage, the participant is monitored for their time to complete the quests in the first level of the game, as well as optional quests. Their time is measured automatically by the game to not disturb the player's attention. After that, the players are given a post-questionnaire, containing the NASA Task Load Index (NASA-TLX) where the participants rated their workloads using a 10-point Likert scale.

Analysis of the workshop evaluation yielded positive results, proving the efficacy of the collaborative game-based approach. Furthermore, the participants expressed high satisfaction regarding the workshop, and is overall enjoyable. The participants also expressed the game as conducive to learning, through the effective utilization of learning objects and feedback systems, participants enhanced their grasp of the contents being taught. The NASA-TLX outcomes reveal the workload faced by participants in the game. Although the participants indicated moderate levels of mental, physical, and time-related demands, the reported frustration indicates need for refining task design to reduce cognitive strain and improve overall user engagement.

Although Holly et al. (2024) provided empirical support of using multiplayer game-based learning as learning material for a programming workshop, the study had a number of limitations, such as the small sample size of the detailed analysis group. This, combined with the lack of rigorous analysis techniques could result in biased conclusions. Furthermore, the diverse social and cultural backgrounds of participants, combined with low attention levels, necessitated the use of brief questionnaires in simple language, potentially affecting the data's ability to fully capture their experiences.

2.2.5 ChemisTree: A Novel, Interactive Chemistry Game to Teach Students about Electron Configuration

ChemisTree is a chemistry game developed by Goldman et al (2024) that utilizes lego pieces to help students visualise and understand electron configurations. Participants targetted for the study were first year undergraduate Chemistry students. ChemisTree is a collaborative game designed for teams of students to work together in constructing orbital diagrams. The game utilizes LEGO tiles to represent electrons and plates to represent orbitals, and students build the electron configurations of their assigned electrons.

Goldman et al. (2024) posits that while there are numerous innovative games available that cover a wide range of chemistry topics, games specifically focused on electron configurations are less common in the literature. The researchers also found that existing games primarily address electron configurations of atoms, with even fewer addressing ions. The topic is fundamental in the chemistry major, as it provides insight into the behaviours of elements, and an important concept to grasp. Active learning techniques like game-based learning and collaborative learning, have shown to be effective in reinforcing concepts in chemistry. Realizing the lack of games related to the subject, its importance as well as its potential, Goldman et al. (2024) developed ChemisTree,

The study was conducted with a total 146 undergraduate students. The participants played the game in the same week they were lectured about the topic. Before playing the game, participants viewed a tutorial video on how to play the game. The players are then divided into three teams of two, where the teams will compete with each other. Next, players use a random number generator to choose the round they would like to play. Round 1 corresponds to the electron configuration of atoms, whereas Round 2 corresponds to the electron configuration of ions. After that, the first team constructs the assigned electron configuration using the LEGO tiles. Upon completion, the team compares it to the answer and is scored. After that, the next team is given the board, and the game will continue until all teams have completed their turns. The class instructor also assisted in the process by facilitating discussion among the teams, as well as identify conceptual difficulties that may require whole-class discussion. The team with the highest score wins.

Pre-tests and post-tests were utilized by the study. The pre-test was given to students before they watched the tutorial video, and the post-test was given after the students finished playing ChemisTree. Both pre-test and post-test questions were identical, containing 5 questions about constructing electron configurations. Paired-Samples t-test was used in the study. The questions in both tests correspond to the learning objectives of the game, which are (a) using the Aufbau principle to determine the electron configuration of atoms, (b) use the Pauli exclusion principle to determine the electron configuration of atoms, (c) Hund's rule to determine the electron configuration of atoms, followed by (d) determine the electron configuration of ions.

The analysis of the results showed that the pre-test scores had an overall average of 51.2% ± 2.5% , while the post-test scores averaged 62.7% ± 2.4%. The Paired-Samples t-test revealed that this 11.5% increase in scores from the pre-test to the post-test was statistically significant. The pre-test and post-test results collectively demonstrated an improvement in students' ability to accurately answer questions related to the four learning objectives of the ChemisTree game. This suggests that the game effectively enhanced students' understanding of electron configurations and related concepts.

Although the study yielded positive results, it was not without limitations. For example, the students expressed that the type of LEGO pieces used in the study was a source of frustration in the feedback form. Next, the nature of the game being a LEGO set that has to be passed around the teams could have impeded in the attention of the players by having downtime while waiting for their turn. The game is also physical in nature, meaning that players cannot play ChemisTree outside of class or during their free time.

2.2.6 Discussion of Related Works

All of the papers reviewed used pre-tests and post-tests. Out of the 5 papers reviewed above, only two had used rigorous testing and analysis tools to measure the improvements between the pre-test and post-test. This could result in biased conclusions. Additionally, the ChemCOMPETE-II paper lacked a control group to compare the physical version and the digital version of the game. The study could have provided a more comprehensive evaluation of the game's effectiveness by comparing the impacts of physical and virtual modes on players' experiences and outcomes.

2.3 Review of similar games

This section reviews educational chemistry games that have been developed to teach Chemistry. The reviewed games will be analysed based on the chemistry topic, the genre, user interface design, and supported platforms.

2.3.1 ChemPOV

ChemPOV is a 2D multiplayer board game centered around the topic of organic chemistry developed by Fung et al. (2021). The game is developed using the Unity Game Engine compatible with Microsoft Windows computers only. However, support for additional popular platforms, including macOS, is currently under development. The game is an online digital board game that aims to enhance student engagement by allowing players to compete with their friends in completing reaction synthesis schemes as quickly as possible. ChemPOV features a random board layout to provide a unique experience every time a new game is started.

Upon running ChemPOV, the players are greeted with the main menu, as shown in Figure 2.7. The player is prompted to enter their name, and optionally the room name in case they are joining a friend. Then, the player is required to choose their avatar, as shown in Figure 2.8. These avatars are modelled after notable scientists who have significant contributions to chemistry. Once every player has chosen an avatar, the game can start.

Figure 2.7: The main menu of ChemPOV.

Figure 2.8: Avatar Selection.

Players will be presented with a screen displaying the game map. This map includes the tile options on the left (Figure 2.9a), the Player Card at the top right (Figure 2.9b), and the Instructions/Inventory tab at the bottom right (Figures 2.9c and 2.9d, respectively). The Inventory tab can be opened and closed by clicking on the small rectangular tab. ChemPOV enables players to strategize which tiles they want to move to after reviewing their Player Card. The instructions tab provides guidance on player actions, such as spinning the die or selecting their destination tile. The Player Card reveals the main reaction scheme that players must solve to win the game. All players begin their turn at the center of the board, marked with an atom symbol. To determine their next move, players roll an onscreen tetrahedron die and commit to moving to a tile based on the number displayed. Every possible tile that the player can choose to land on gets highlighted after they roll the dice.

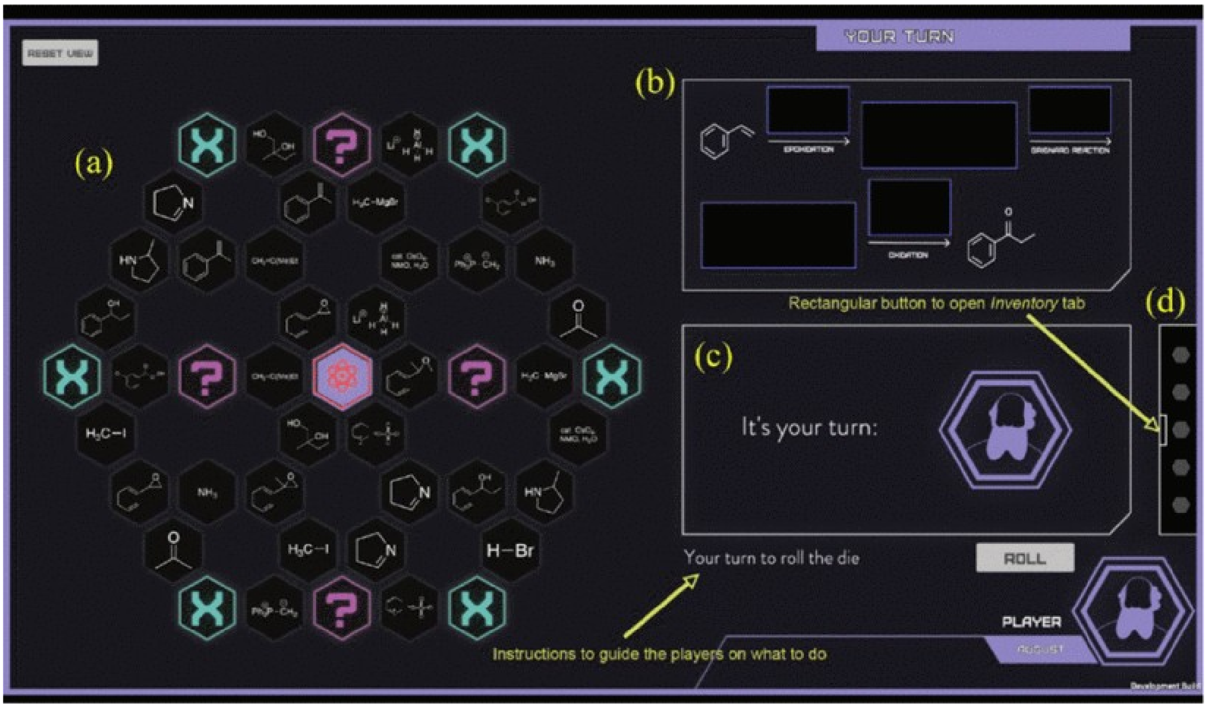

Figure 2.9: User Interface of ChemPOV. (a) map and tiles. (b) Player Cards. (c) Instructions tab. (d) Inventory tab.

Upon choosing on a tile, a Multiple-Choice Question will be displayed. As shown in Figure 2.10, the question is displayed on the left hand side, with space underneath it to show a 3D model of the chemical in question. On the right hand side, the four options are displayed for the player to pick. The time for the player to complete the question is 15 seconds, which is displayed in a timer on the top right. If the time remaining is less than 5 seconds, it will blink in red. If the chosen answer is correct and within the time limit, the player is allowed to stay on the tile. Additionally, a Chemical Card will be given to the player that they can use to fill in the organic synthesis scheme in their Player Card. Conversely, if the answer is wrong or the player takes too long to answer, the player will have to stay at the tile they were on before the turn. The answer to the question will be highlighted, as well as explanations on why the chosen answer is wrong.

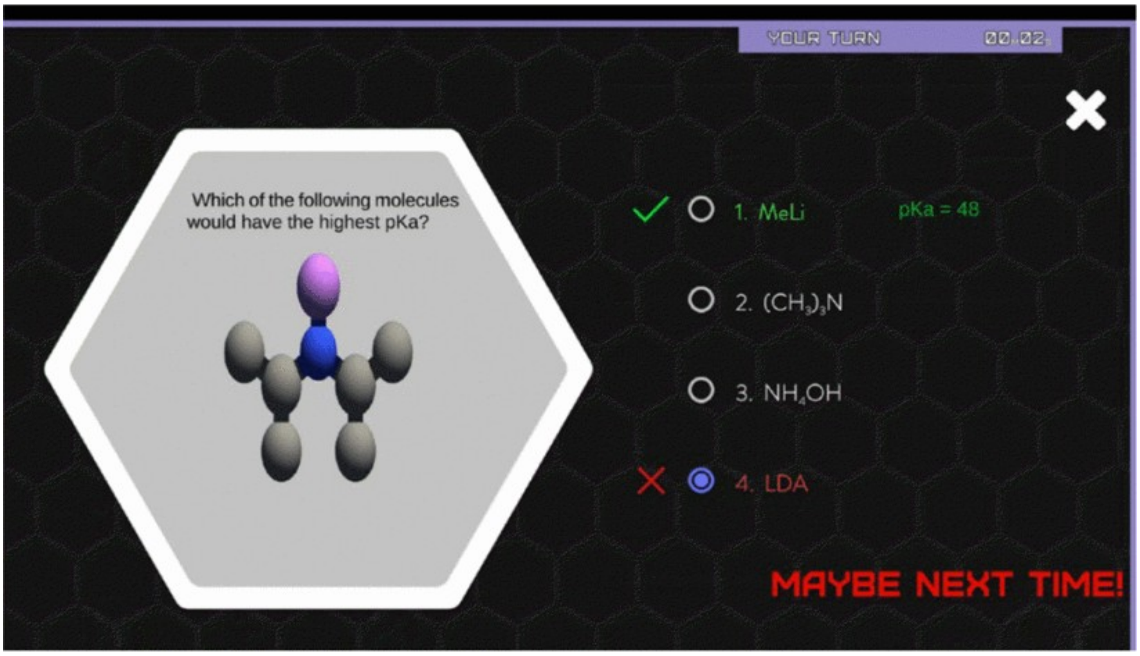

Figure 2.10: An example failed Multiple Choice Question. The answer is shown with reasons.

In addition to normal tiles, the game also has Teleport Tiles and Chance Tiles. Upon landing on a teleport tile, players can teleport to anywhere on the board marked with an “X”. The Chance Tile allows the player to try their luck by choosing a Chance Card, which can have negative or positive effects for the player. For example, one Chance Card allows the player to select a Chemical Card, while another requires the player to remove every Chemical Card from their inventory. The Chance cards are also accompanied by narration to serve as context on why it was given its name based on real-life laboratory and research scenarios. The fastest player to complete their Player Card wins the game.

In summary, ChemPOV has a great user interface that is simple enough for anyone to understand. It also has visual indicators for game-critical information like the time limit and the possible tiles that the player can land on. Despite being a multiplayer game, it can be played as a singleplayer game, which can be great for students that want to try it alone or use it as study material. The questions, answers and explanations are insightful, rewarding players with deeper understanding of the chemical concepts. However, the time taken to complete a match varies a lot due to the randomness of the Chemical Cards given. Consequently, students that allocate their time to play the game might exceed their allotted time, which can disrupt their schedule. Furthermore, the randomness of the game, which does not rely nor care about the player’s understanding of the topic, could be a potential point of frustration. The game also does not show anything during an opponent’s turn which can detach the players from the experience.

2.3.2 2.3.2 Unreal Chemist – Chemistry Lab

Unreal Chemist is a sandbox simulation game developed by PixelMiller (2024) for students, educators, or enthusiasts to learn the Periodic Table and Chemical Reactions. Unreal Chemist is developed using Unity Engine, and is only available for mobile devices. The game allows for many activities, such as mixing substances, burning, solubility simulation, periodic table viewer, equation balancer, and mixing game. However for this review, only the mixing game will be reviewed in full as it is the only part of the application that has game-related aspects. Other modes will be reviewed in brief. Unreal Chemist aims to be a mobile Chemistry Laboratory in mobile devices, and can only be played as singleplayer.

Running the game will show the main menu, as shown in Figure 2.11. It shows the various options the game has for the player to choose. Mixing mode is the same as the mixing game, where the player can mix solutions freely without a time limit, or goal. Burning mode is where the player can burn solid or liquid substances like Strontium or ethanol, and view the color of the flame produced by the substance. The periodic table viewer allows the player to view the elements in detail. The equation balancer mode is also part of the mixing game, where the player can mix water with acidic or basic solutions together to simulate the expected pH value. Equation Balancer mode is like a calculator, where the application balances a Chemical equation for the player after inputting a chemical equation into a text box.

Figure 2.11: Unreal Chemist's Main Menu

The mixing game has numerous levels for the player to advance through, but in general, the goal is for the player to mix two chemicals together to produce a desired solution of a desired concentration. The Level Select screen is shown in Figure 2.12. Playing the mode for the first time prompts a tutorial that shows how to play the game. The star count on the top right of the screen shows the total amount of stars the player has gained by playing the game mode. Every completed level displays the amount of stars the player achieved in that level. In addition to the "Apprentice" difficulty levels shown in Figure 2.12, there are three other difficulty levels named "Beginner", "Master" and "Legend" which can be seen by scrolling down. Every level can be chosen by tapping.

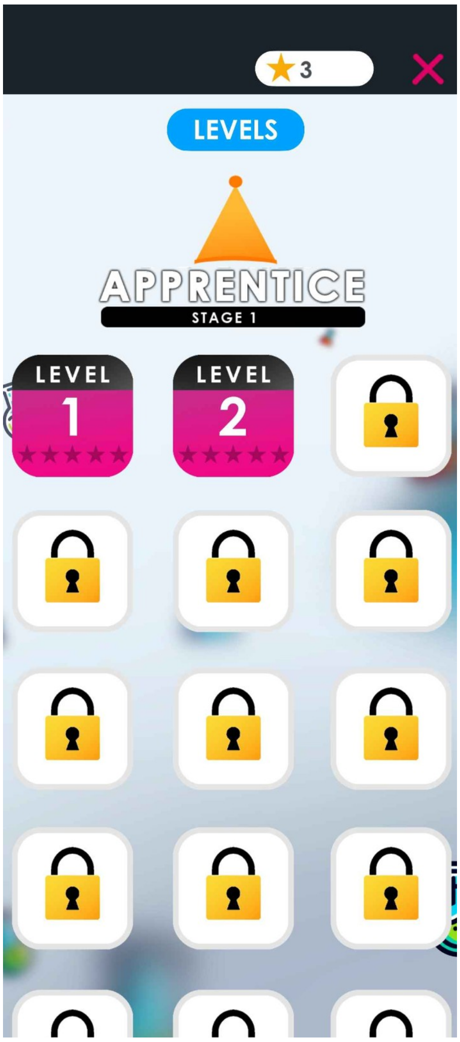

Figure 2.12: Unreal Chemist's
Level Select Screen

After choosing a level, the objective and time limit of the level is displayed. Players can return to the Level Select screen by pressing the "CANCEL" button or proceed into the level by pressing "ACCEPT". Upon proceeding, the scene switches to the Mixing Game, which is shown in Figure 2.13. The Chemical chooser, highlighted in Figure 2.13a is where the player can choose a chemical solution to pour into the beaker. The slider in Figure 2.13b controls the volume of solution flowing into the beaker. Once a solution of any volume is poured, the detail panel showing the name, volume and concentration of the solution is displayed, highlighted in Figure 2.13c. The maximum volume of solution poured into the beaker is 350 millilitres. The player can pour the liquid out from the beaker by pressing the purple button highlighted in Figure 2.13d. The time limit, and a hint button can be seen in Figure 2.13e. Once the time limit is reached, or the player presses the check button in Figure 2.13f, the game assesses the player's solution and scores it by giving stars. Also, a burst of confetti appears when either happens.

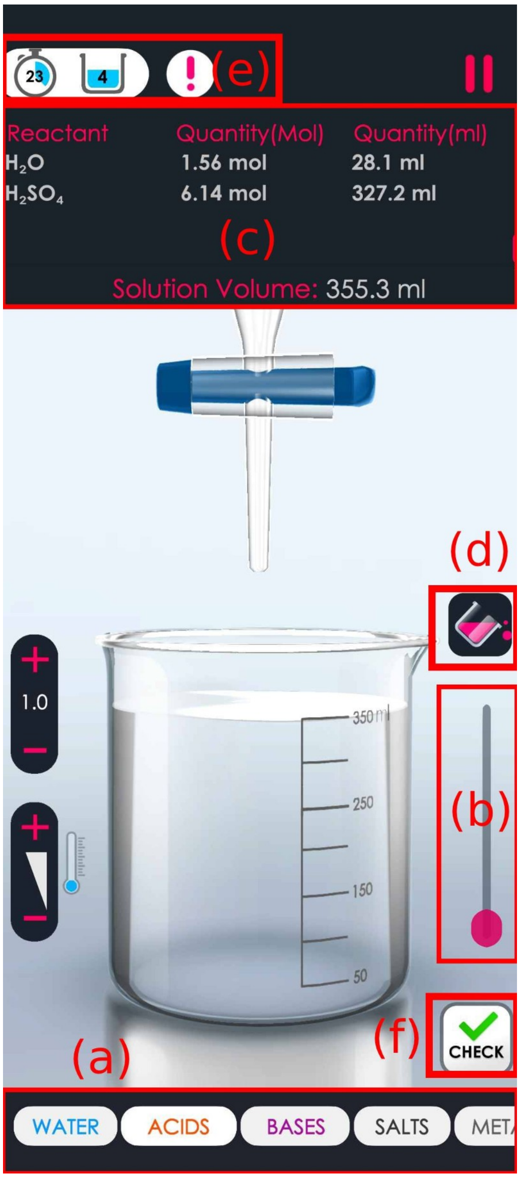

Figure 2.13: User Interface of the mixing game.

Overall, the application is very well made. The user interface is intuitive while being stylized. Every mode is very well put together, especially in terms of graphics. Every solution changes its properties upon reacting with the proper solutions, like colour changes and precipitation. Each chemical substance burns with its actual colour in real life, like red with ethanol and bright white with magnesium. As for the mixing game, the game could be better if it supplied the user with hints on how to get the stars. While it does have a hint button, it only reiterates the objective of the level. The method to get full stars seem to be related to the order of which the solutions are added – a safety practice in chemistry, but it was not properly communicated in the game.

2.3.3 Chemistry Infinity

Chemistry Infinity is a 2D puzzle game developed by MidnightBisons (2016) centered around molecular bonds. The game is of the match three genre of video games, where the player has to complete a level by removing all atoms in the screen by forming the structure of a molecule via bonding atoms. The game is a singleplayer game, and is free to play on Windows and Android platforms. The main menu of Chemistry Infinity is shown in Figure 2.14. Pressing “Play” will switch the scene to the level select screen, shown in Figure 2.15.

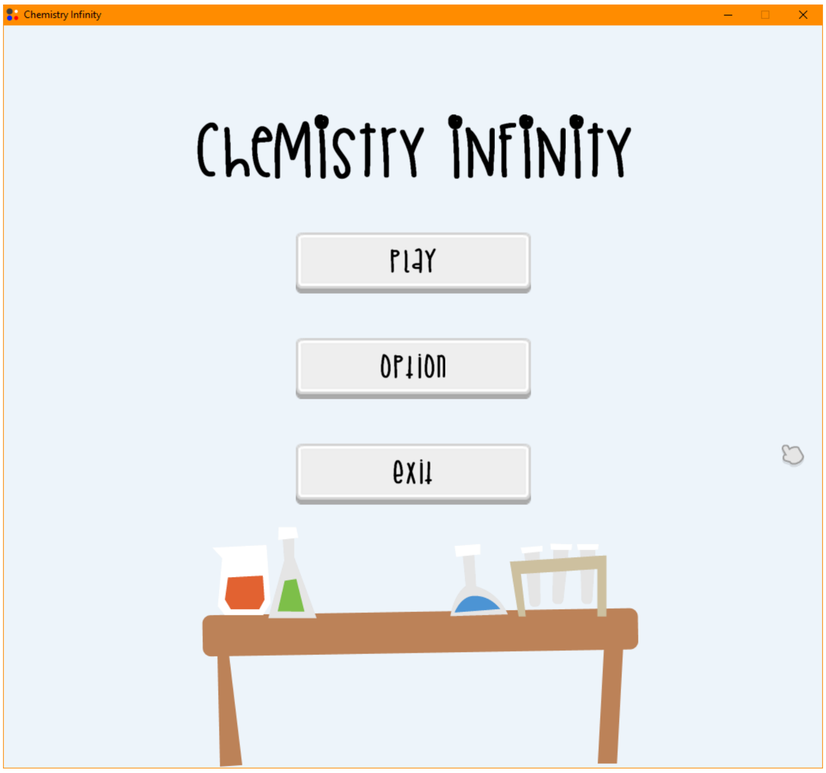

Figure 2.14: Main menu of Chemistry Infinity.

Figure 2.15: Level select of Chemistry Infinity

A level can be chosen by clicking on any of the yellow buttons. Upon choosing a level, the puzzle game can be played, as shown in Figure 2.16. The objective of each level vary, but fall into two categories: the first requiring the player to create a specific amount of molecules using all the atoms in the screen; the second requiring the player to create a specific molecule. A molecular bond can be made by holding and dragging an atom into another. This is considered a "turn" and levels have different turn limits. If the molecular bond created is a valid substance, like a Hydrogen-Water-Hydrogen molecule (water), it is considered "satisfied" and removed from the screen. However, making random molecular bonds does not mean it will remove it from a screen, for example, connecting Hydrogen and Carbon (unless it is required for the player to do so like in the first couple of levels). Additionally, some atoms require more than one bonds to satisfy, like Nitrogen requiring three bonds to be satisfied. A button on the bottom of the screen can be clicked to switch between bonding and debonding modes, similar to drawing and erasing bonds. Hitting the turn limit results in failure, and the player has to start the level again. Once the level requirements are satisfied, the level is considered complete.

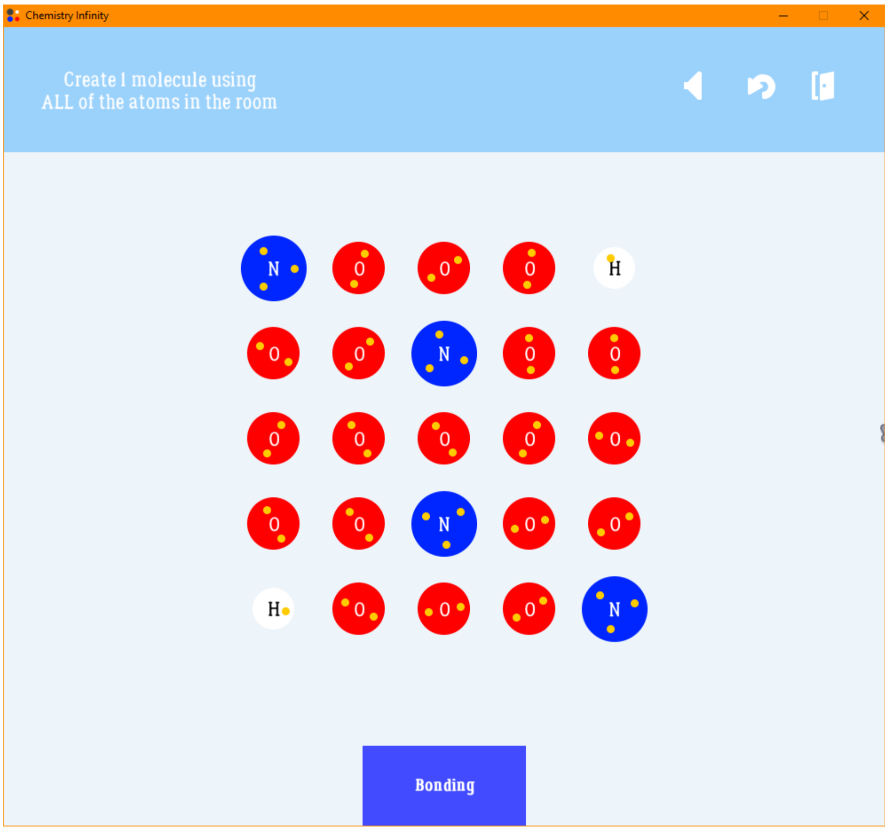

Figure 2.16: A sample level in Chemistry Infinity

The user interface is slightly stylized, while being simple and easy to understand without any hassle. However, the game does not have vital user interface buttons in places it is needed, such as a return to menu button and options in the level select screen, and an indicator for remaining turns for each level. Despite it being a crucial aspect of game, it is not visually communicated in any way, other than in the failure screen. Furthermore, Chemistry Infinity does not give any hints whatsoever, so some trial and error is required. Overall, the game mechanic is intuitive, allowing for a casual gameplay style and the same can be said for the artstyle. While the flaws listed above does not affect the gameplay in a significant way, but amending them by adding User Interface elements could better improve the gaming experience.

2.4 Comparison with Proposed Project

The proposed project will be compared with the research works that have been carried out by other researchers to study the efficacy of using collaborative learning in Chemistry and STEM related subjects. The digital collaborative Chemistry game developed in the project will also be compared to games related to Chemistry that have been developed.

2.4.1 Comparison of Related Works with Proposed Project

The intended age group of students indicates the educational level or grade that the digital game is tailored for. The majority of the reviewed research papers targetted undergraduate students, with Rychkova et al. (2020), Lam et al. (2024) and Goldman et al. (2024) targetted first year undergraduate Chemistry students, and Pang et al. (2023) targetted third year undergraduate students in general. Holly et al. (2024) targetted women aged 15 to 25 years old, without regard for any skill level with programming. Since these research papers reviewed has targetted undergraduates, and none targetted a younger age group specifically, the targetted age group for the proposed digital collaborative Chemistry game will be students in the tenth grade, or Form 4 students.

The focused Chemistry topics are the targetted Chemistry knowledge or skills that can be gained by the students after engaging with the collaborative digital game. All of the reviewed papers that aim to teach Chemistry develop their games around undergraduate-level

Chemistry. Rychkova et al. (2020) opted for electron orbitals, Lam et al. (2024) delved into substitution and elimination reactions of alcohols, Pang et al. (2023) covered introductory chemistry concepts, and Goldman et al. (2024) examined electron configurations in their respective studies. Since there are lack of studies targetting Form 4 students, the proposed game will focus on the third chapter from the KSSM Form 4 Chemistry syllabus, which is *The Mole Concept, Chemical Formula and Equation.*

A digital game's genre is the type or style of gameplay the game has. Rychkova et al. (2020), Holly et al. (2024), and Pang et al. (2023) developed games in the puzzle game genre, while the games developed by Goldman et al (2024) and Lam et al. (2024) fall under the board game genre. The games developed by Goldman et al (2024) and Rychkova et al. (2020) are competitive games, requiring groups of players to face off against each other for the highest score. The games developed by Holly et al. (2024), Pang et al. (2023) and Lam et al. (2024) have no competitive aspects to it, instead requiring the players to work together to achieve a common goal. It is important to highlight the existence of competitive aspects in a game, as the literature review of Holly et al (2024) states that female students are less likely to enjoy a game with competitive aspects. Overall, the games utilized by the reviewed papers require a degree engagement where the player has to think critically to solve the problem, to which the puzzle genre requires the players to. Hence, the proposed game will be a 3D non-competitive, puzzle game.

Every research paper reviewed utilized pre-tests and post-tests to evaluate the effectiveness of the designed game. However, out of the five reviewed papers, only Goldman et al (2024) and Lam et al. (2024) utilized rigorous analysis methods such as Bhapkar and Paired-Samples t-tests to measure the effectiveness of their developed games, while the rest used mean values. It should be noted that Lam et al. (2024) lacked a control group to compare the physical version and the digital version of the game. To more accurately assess the impact of collaborative learning within a digital game environment, pre-tests and post-tests to will be employed for the proposed project to gather comprehensive data.

Table 2.1: Comparison between existing digital collaborative game-related research works and proposed digital game project.

Research work	Targetted Student Age Group	Focused Chemistry Topic(s)	Educational Game's genre	Evaluation Method
Orbital Battleship: A Multiplayer Guessing Game in Immersive Virtual Reality	First Year Undergraduate students	Electron Configuration	Competitive Puzzle game	Pre-test and Post-test evaluations
Exploring the Use of an Avatar-Based Online Platform to Facilitate Social Interaction in Laboratory Sessions	First Year Undergraduate students	Chemistry Laboratory Experiments	Puzzle game	Pre-test and Post-test evaluations
The Online Version of CHEMCompete-II: An Organic Chemistry Card Game to Differentiate Between Substitution and Elimination Reactions of Alcohols	Third Year Undergraduate students	Substitution and Elimination Reactions of Alcohols	Card game	Pre-test and Post-test evaluations
FemQuest - An Interactive Multiplayer Game to Engage Girls in Programming	15 – 25 year olds	-	Puzzle game	Pre-test and Post-test evaluations and NASA -LTX test for mental load assessment

Research work	**Targetted Student Age Group**	**Focused Chemistry Topic(s)**	**Educational Game's genre**	**Evaluation Method**
ChemisTree: A Novel, Interactive Chemistry Game to Teach Students about Electron Configuration	First Year Undergraduate students	Electron Configuration	Competitive Puzzle game	Pre-test and Post-test evaluations
Objective Terminal	Form 4	The Mole Concept, Chemical Formula and Equation	3D Puzzle game	Pre-test and Post-test evaluations

2.4.2 Comparison of Similar Games with Proposed Project

Table 2.2 shows a summary of the comparison between three reviewed Chemistry games and the proposed collaborative Chemistry game.

The three reviewed games have different genres altogether. Chemistry Infinity is a simple puzzle game, Unreal Chemist – Chemistry Lab is a sandbox simulator, and ChemPOV is an online board game. However, ChemPOV does have some puzzle-like elements such as the player card which the player need to complete in order to win. All of these games are developed in 2D, with no clear narrative that might motivate the player to progress through the game. Even so, Chemistry Infinity required the most engagement among all of the games reviewed, demonstrating the efficacy of puzzle games to engage players in problem solving activities. As such, Objective Terminal will incorporate the puzzle game genre while making use of 3D environment to differentiate it from other games.

The reviewed games encompassed a diverse range of chemistry topics. ChemPOV focused on organic chemistry, Unreal Chemist centered around the periodic table and reactions and Chemistry Infinity covered molecular bonds. Only the chemistry topics of Unreal Chemist and Chemistry Infinity are related to high-school chemistry, whereas the topic covered in ChemPOV is undergraduate level organic chemistry. The topic chosen for Objective Terminal will be Chapter Three of the KSSM Form 4 Chemistry syllabus, which is *The Mole Concept, Chemical Formula and Equation*.

The game's platform refers to the software or hardware environment on which the game's application can operate. All of the games reviewed are available on commonly-used platforms such as Windows and Android. ChemPOV is a browser game, so it can be played on any platform. Unreal Chemist is an Android and IOS exclusive, and Chemistry infinity is compatible either on Windows or Android. It is paramount that a game releases to the most popular platform to ensure it reaches to the widest audience, especially for a digital game. Since Unreal Engine will be used for the development of Objective Terminal, the game is to be compatible with Windows.

Table 2.2: Comparison between existing educational chemistry games and proposed collaborative Chemistry game.

Game Title	**Developer/Publisher**	**Educational Game Genre**	**Focused Chemistry Topic(s)**	**Compatible Platforms**
ChemPOV	Fung et al. (2021)	2D Board game	Organic Chemistry	All browsers that support HTML5
Unreal Chemist – Chemistry Lab	PixelMiller (2024)	Sandbox Simulation game	Periodic Table and Reactions	Android and IOS
Chemistry Infinity	MidnightBisons (2016)	2D Puzzle game	Molecular bonds	Windows and Android
Objective Terminal	Imran Harriz bin Madzalan	3D Puzzle game	The Mole Concept, Chemical Formula and Equation	Windows

2.5 Summary

To summarize, the applications of digital collaborative games for teaching mathematics have been comprehensively reviewed. In particular, five research works related to the development and implementation of Chemistry and STEM subjects have been identified and analysed. Additionally, three educational games about mathematics that are available online have been identified and reviewed. Comparisons of these research works yielded insights that have been helpful for determining key aspects of the proposed digital collaborative game project.

Chapter 3: Methodology

3.1 Introduction

A development methodology is crucial for development of software, as it provides developers a guide to follow, and keep track of progress. This is especially true for game development, where requirements change on a day to day basis, either influenced from within the development personnel, stakeholders or player feedback. SCRUM will be used for this project, as it is the most commonly used methodology for game development.

3.2 SCRUM Methodology

Figure 3.1 shows the steps involved in the SCRUM methodology.

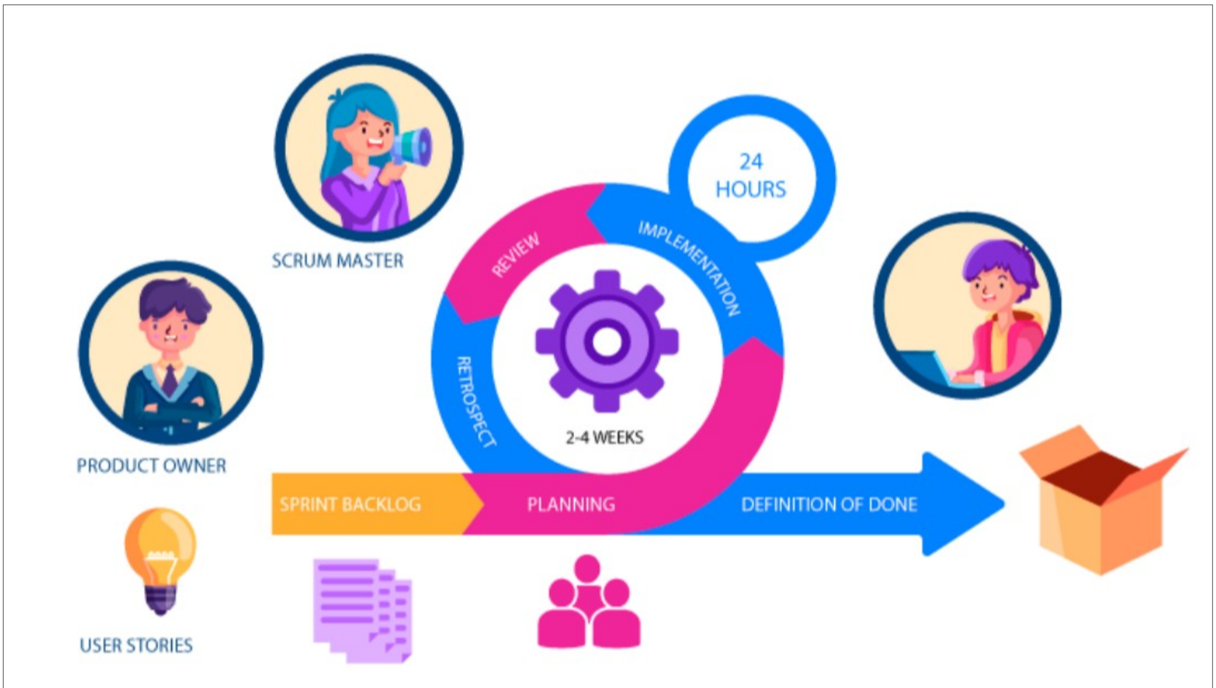

Figure 3.1: SCRUM Methodology

SCRUM is an agile methodology, it is an iterative and highly adaptive to change. The methodology prioritizes developing working software in short cycles, iterative called sprints. These sprints typically lasts for one (1) week to four (4) weeks. These prints have four main phases, listed below:

1. Sprint Planning
2. Implementation
3. Sprint Review
4. Sprint Retrospective

Additionally, SCRUM requires the development personnel to assume special roles, and items crucial to the methodology called “artifacts”. These artifacts include the Product Backlog and the Sprint Backlog. The Product Backlog is the list of features that the product needs to have, acquired by requirements given from players and the Product Owner, called user stories. During a Sprint, features from the Product Backlog are selected by priority and put into a Sprint Backlog. The features in the Sprint Backlog are the features which the developers have to work on during the Sprint.

As shown in Figure 3.1, SCRUM has roles such as the Product Owner, the SCRUM Master and the Developer. Since this project is required to be done alone, these roles will not be used in this project. The responsibilities of these roles will be assumed by Imran, namely the responsibilities of the Product Owner and the Developer. According to Scrumguides (2022), the Product Owner is responsible for maximizing the value of the product resulting from the work of the developers by prioritizing features, maintaining the Product Backlog artefact and project schedule. Whereas the Developer role is responsible for creating the product in each sprint, following the features listed in the Sprint Backlog and the feature's acceptance criteria (Scrumguides, 2022). These responsibilities, as well as the methods to carry out the roles will be used by Imran in this project.

3.2.1 Planning

Sprint Planning is where the most of the User Stories (requirements) are gathered, which can be obtained from research, players or subject matter experts. Since the targetted age group for the project is Form 4 students, a survey has been handed out to understand which topics they struggle with and why. Additionally, two Form 4 Chemistry teachers have been interviewed to get a teacher's perspective on why students struggle with the subject. The literature reviewed in Chapter 2 will also be used as a source of user stories to guide the project. From the interview and survey, user stories can be inferred and turned into requirements, which are then put into a Product Backlog.

Section 3.3.1 covers the interview with Form 4 Chemistry teachers. Next, the survey results from students are presented, followed by a detailed list of proposed game features (Product Backlog, non-exhaustive). This section is closed with an in-depth explanation of game mechanics which includes a flowchart of the proposed game.

3.2.2 Interview with Chemistry Teachers

Two Chemistry teachers who teach both Form 4 and Form 5 have been interviewed as part of the requirement gathering process. These teachers are from the same secondary school in Kuching, Sarawak. They were chosen to obtain a teacher's perspective on the regarding problems that students face when learning Chemistry. Prior to each interview session, teachers were required to read and complete a consent form, signifying their voluntary participation.

Appendix C includes the consent form and the interview questions utilized during the sessions.

The questions were designed to explore the teacher's level of expertise and familiarity with various teaching methods, particularly collaborative learning techniques and game-based learning techniques. Additionally, these questions seek to understand the views these teachers have regarding the impact of conducting collaborative chemistry sessions via multiplayer game, and what could improve student's understanding of Chemistry. The first question asked about their years of experience teaching Chemistry. Teacher A has been teaching for 13 years whereas Teacher B has been teaching for one year.

Opinion on which Form 4 Chemistry topic is the hardest for students to grasp.

Both teachers state that the Mole Concept and Chemical Formula is the hardest topic for students to grasp particularly due to the formulas and problem solving methods to balance the Chemical equation. Teacher A added that Chemical Bonds and Acid, Bases and Salt are the among the hardest, stating that students have difficulty remembering facts related the topic, such as chemical properties of acids and bases.

Opinion on conducting collaborative learning sessions for teaching chemistry.

Teacher A states that she conducts collaborative learning sessions about two times a week, as it improves students motivation to learn in fun and interactive way. On the other hand, Teacher B conducts collaborative learning sessions sometimes, especially in topics that require memorization of facts. Both teachers believe that collaborative learning improves student's understanding of Chemistry and its concepts, mainly due to the students interacting and exchanging information with each other.

Experience on conducting collaborative learning sessions online.

The fourth question asks about the teacher's experience about conducting collaborative learning sessions online, and what problems or the application have or lacks. Teacher A expressed that the she has experience, but seldom uses it. Teacher B on the other hand often uses these types of application but expressed that the application was limited in features or game modes, and is locked behind a paywall.

Experience on using digital Game Based Learning activities in the classroom.

Both teachers seldom use digital Game-Based Learning activities in the classroom. Teacher A provided no rationale for the limited use, while Teacher B cited the limited time in the classroom as the primary reason.

Opinion on the effects of conducting collaborative learning sessions through an immersive game.

Both teachers agree on the positive effects of conducting collaborative learning sessions through an immersive game, stating games as a fun way to learn. Teacher A agrees that the digital collaborative game can help students with certain topics, while Teacher B expanded by stating that it can especially help with topics that involve memorization of facts and formulas.

Opinion on what a digital collaborative game needs to effectively teach Chemistry

Teacher A stated that the game must be based on a specific learning objective, have good player engagement, and immediate feedback mechanisms. Teacher B points out that the game must have good graphic design to capture student's attention and maintain interest in the game.

3.2.3 Survey with Form 4 Students

The survey was distributed physically on paper to Form 4 students. A consent form was attached to the questionnaire, which the students and their parent/guardian are required to read and complete to signify the parent's/guardian's authorization of their child's participation in the questionnaire. The questionnaire consists of two sections: The first section sought to collect demographic data and gather students' perspectives on the KSSM Form 4 Chemistry subject. The second section aimed to assess students' gaming habits, experiences with games, and their level of interest in educational games that incorporate Chemistry concepts. Appendix D shows the contents of the questionnaire.

68 students participated in the survey. Figure 3.2 shows the gender distribution of the respondents. In total, we% of the 34 respondents were male, which amounts to 23 people, while the majority, 66%, were female, corresponding to 45 respondents.

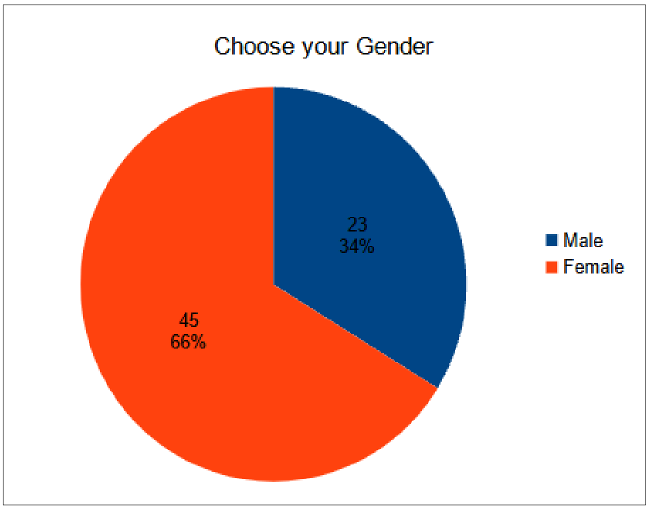

Figure 3.2: A pie chart for the responses of student's gender

Figure 3.3 and Figure 3.4 shows the responses for the question that asked about the difficulty of topics in the KSSM Form 4 Chemistry subject, and the reasons for why the respondents find the selected subjects difficult. Both questions allowed the respondents to select up to three responses. The responses showed that the sixth topic in the curriculum, "Acids, Bases and Salts" is the hardest topic for students to grasp, with 33.2% of the respondents selecting the choice. Furthermore, 30.3% of the responses expressed that the selected topics require extensive memorization of facts and formulas.

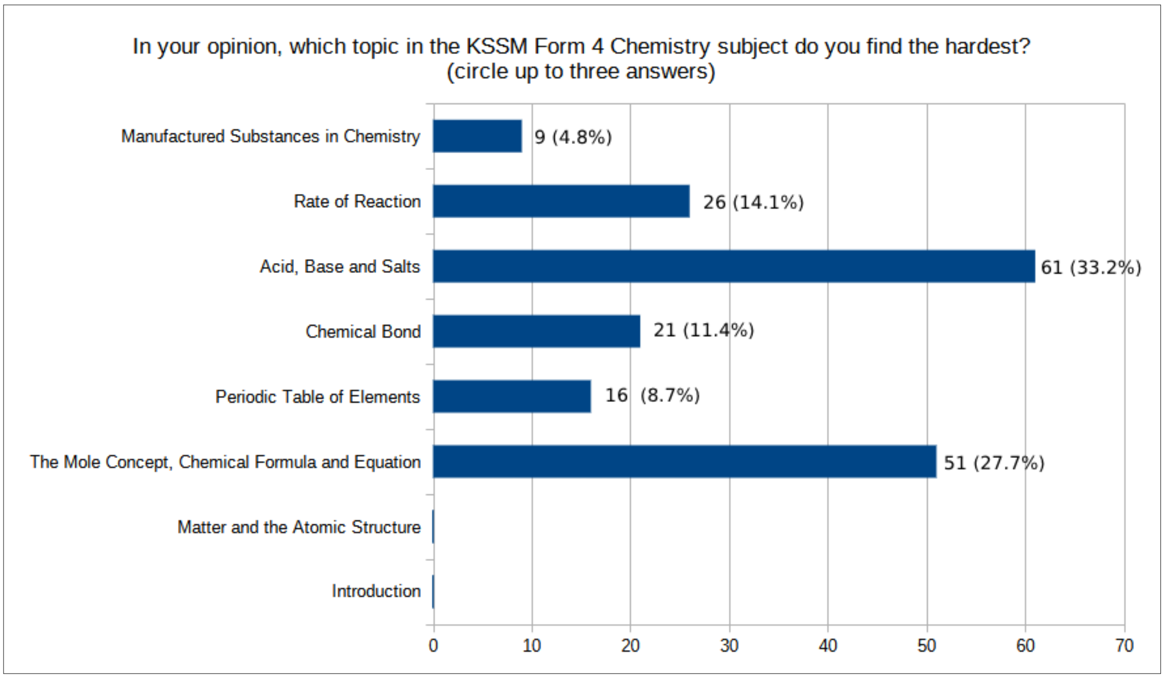

Figure 3.3: The responses for which topic is the hardest is the Form 4 Chemistry Subject.

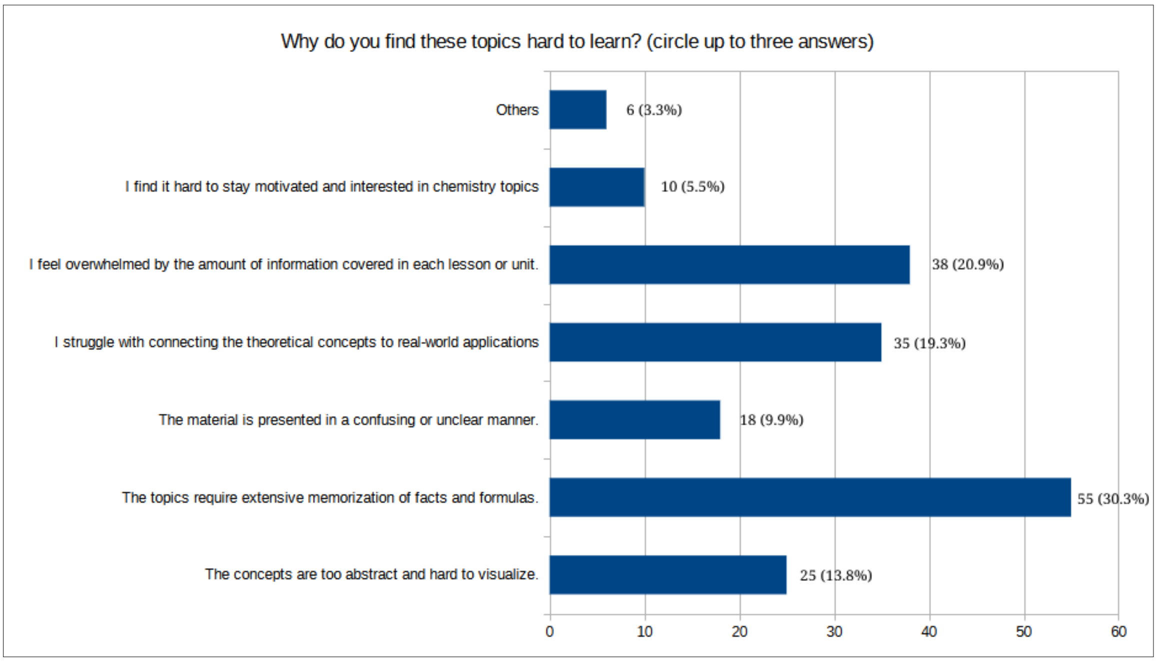

Figure 3.4: The responses for why the students find the topics hard to learn.

Figure 3.5 illustrates the devices utilized by students for gaming. Among the respondents, 88.2% (60 individuals) used mobile phones, 47% (32 individuals) used personal computers or laptops, 26.4% (18 individuals) utilized tablets, and five respondents (representing 7.3% of the total) played games on a video game console. This suggests that mobile phones are the most commonly used platform for playing video games, with personal computers or laptops being the next most popular choice.

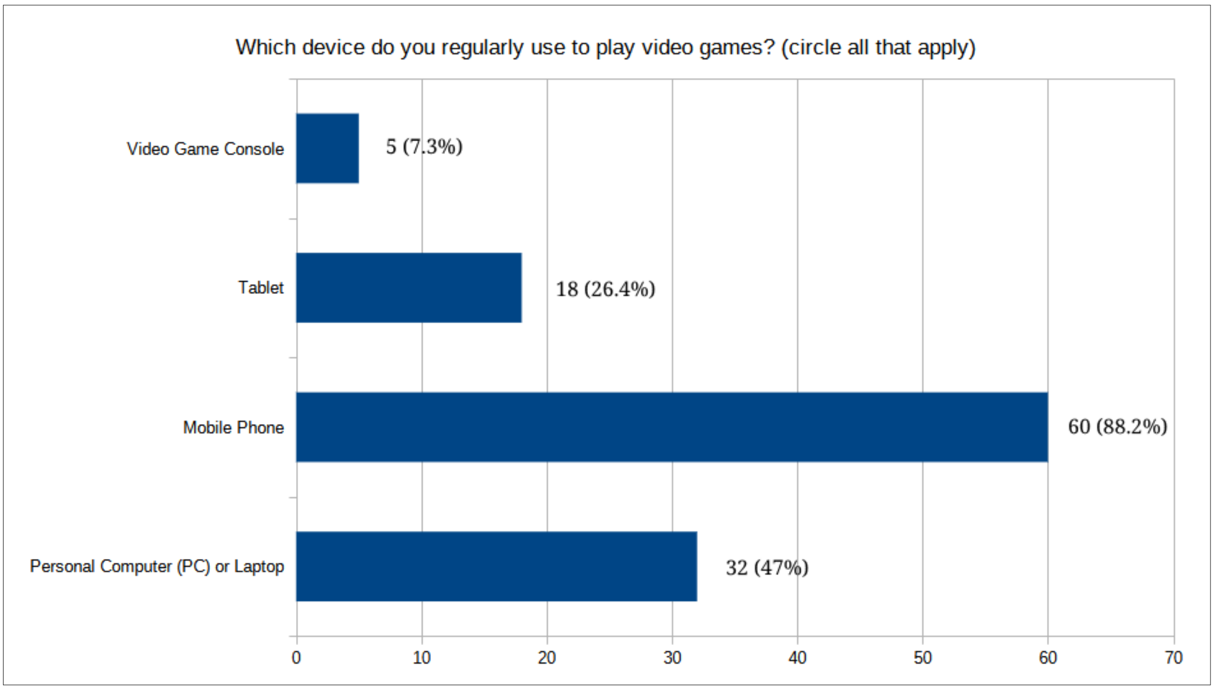

Figure 3.5: Responses for a question that asks which device the respondents use to play video games with.

Figure 3.6 shows the summary of question 2 of section B, which is a group of questions aimed to understand student's attitude towards video games and educational games, as well as the perceived positive effects of video games and educational games as a means to learn The questions are answered using a five-point Likert scale, where respondents can express their agreement or disagreement, ranging from "Strongly Disagree" to "Strongly Agree". The responses regarding the frequency of playing video games and educational games were neural in majority. When asked about their video gaming habits, most respondents had a neutral stance on their regularity. Similarly, when inquiring about their engagement with educational games, over half of the respondents expressed a neutral attitude toward their frequency of play. In the following question, most respondents agreed that they enjoy playing video games. Next, when asked about the perceived positive impact of video games and educational games on helping them to learn, the responses to both questions showed a balanced mix of neutral and agreement. This indicates that the students generally have a positive attitude towards video games and educational games as a means to learn, but generally hold a neutral stance towards playing video games and educational games.

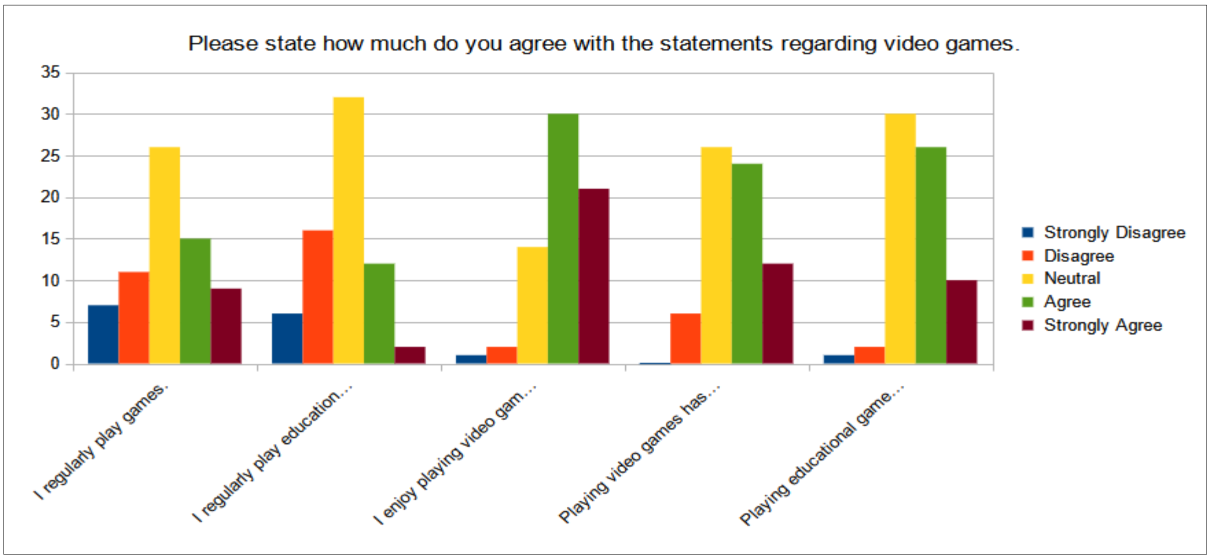

Figure 3.6: The responses for a group of questions that asks (from left to right) "I regularly play video games", I regularly play educational games", I enjoy playing video games", "Playing video games has helped to improved my knowledge" and "Playing educational games have increased by motivation to learn."

Figures 3.7, 3.8, and 3.9 depict the reactions to a series of questions regarding the respondents' level of interest in incorporating Chemistry topics into a video game. The responses are given on a five-point Likert scale, with options ranging from "Very Uninterested" to "Very Interested". Figure 3.7 depicts responses for the asks the interest of being able to play an educational game about the topics of chemistry, with 43% of respondents expressing interest and 14% indicating very strong interest. Next, Figure 3.8 shows the responses for a question that asks about the respondent's interest to be able to play an educational game about Chemistry topics that the respondents struggle in. 32% of the respondents answered "Very Interested" and 31% answered "Interested". Lastly, Figure 3.9 shows the responses of being able to play a multiplayer game about the topics of Chemistry.

28% of the respondents answered "very interested" and 41% of the responses answered "Interested". Overall, the responses showed that significant interest of educational games with the KSSM Form 4 Chemistry topics.

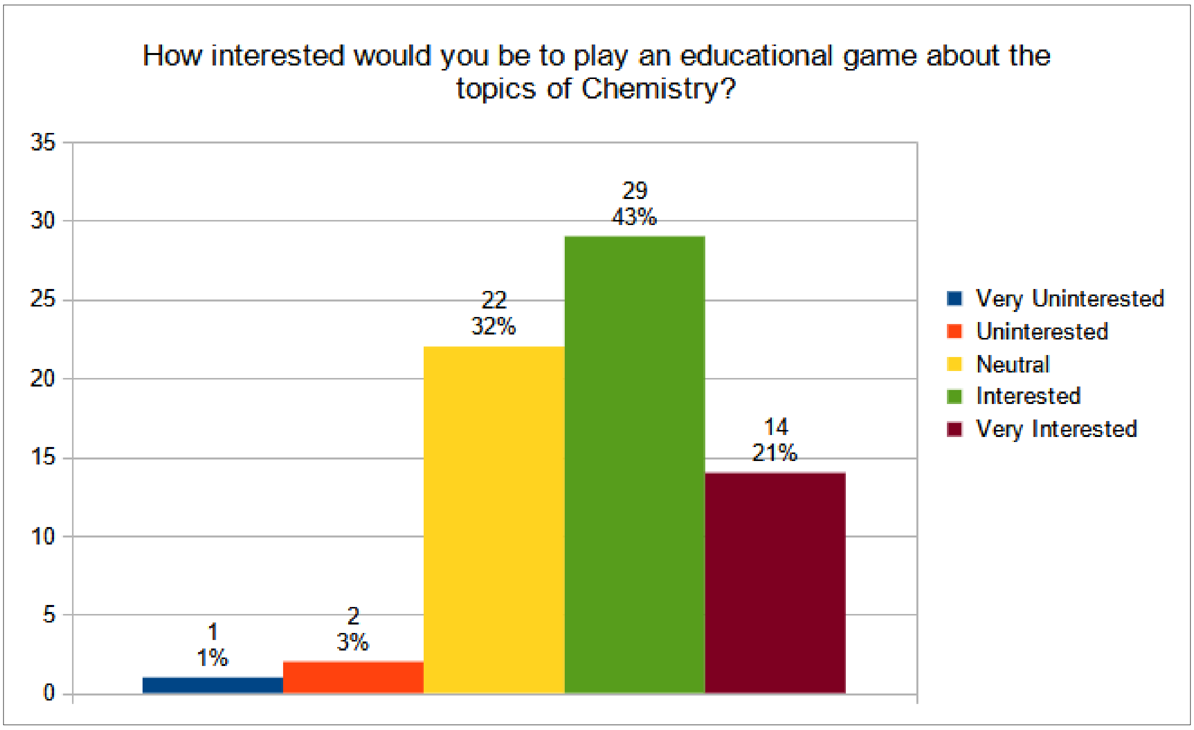

Figure 3.7: Responses for how interested the respondent is to be able to play an educational game about the topics of Chemistry.

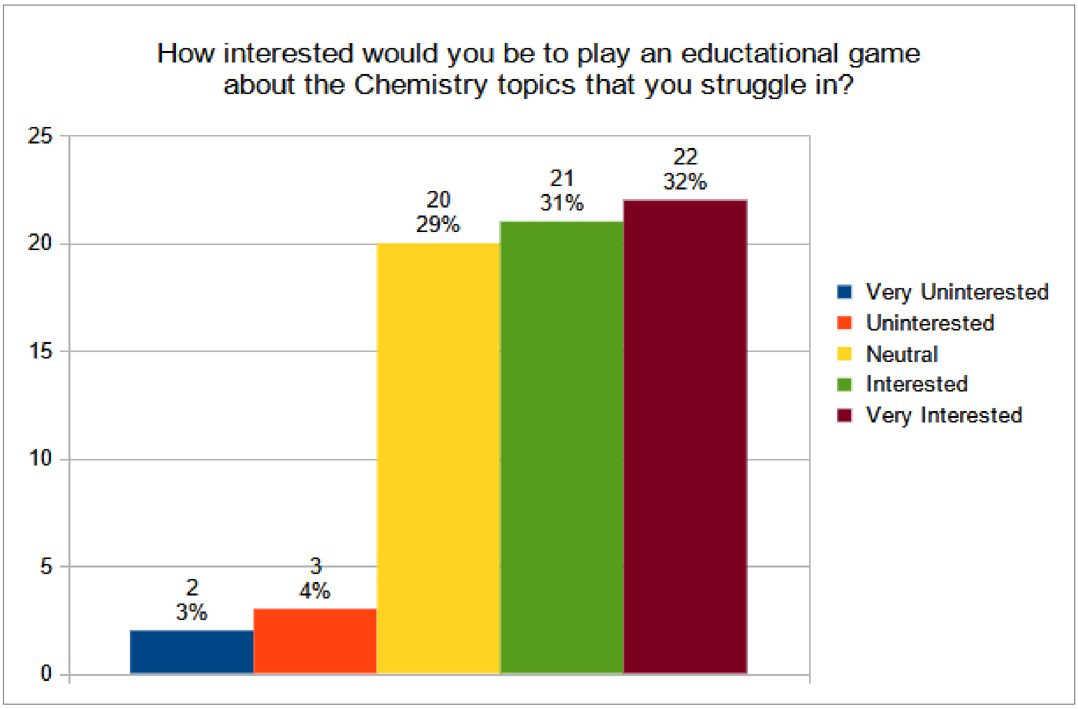

Figure 3.8: Responses for how interested the respondent is to be able to play an educational game based on the topics that they struggle with.

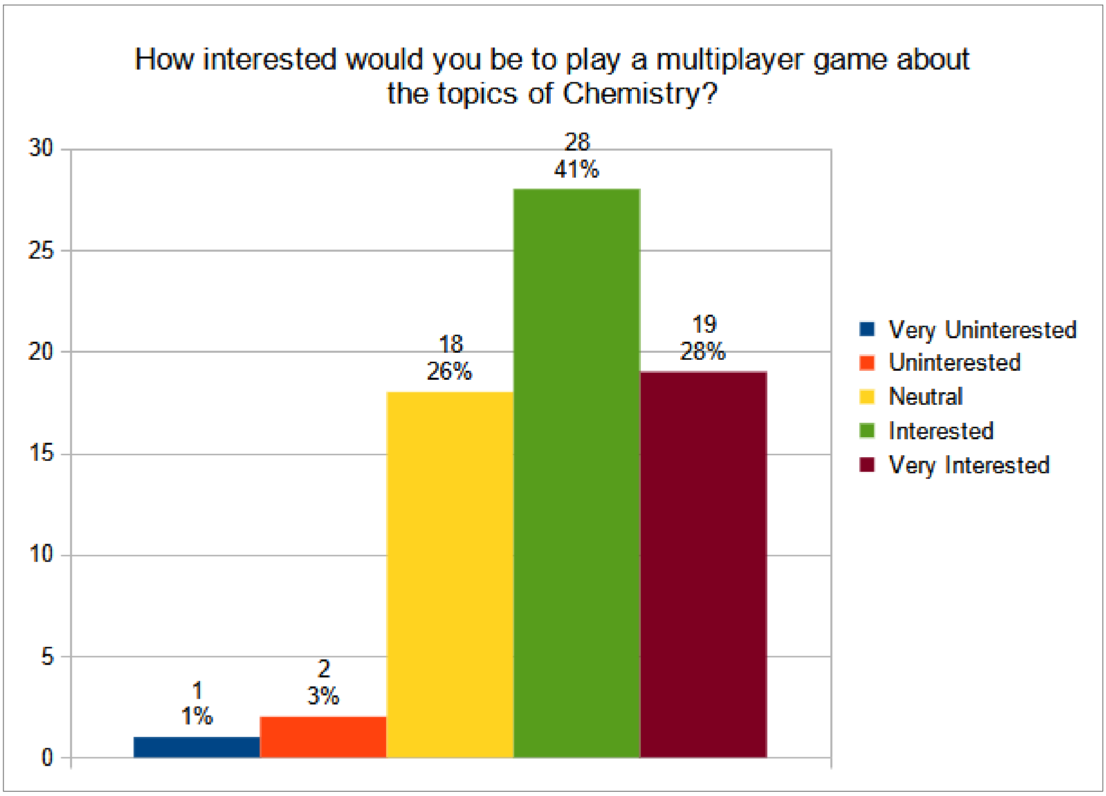

Figure 3.9: The responses for how interested the respondent is to be able to play a multiplayer game based on the topics of Chemistry.

3.2.4 Proposed Game Features and Product Backlog

This section describes the proposed game features and Product Backlog. According to Schwaber and Sutherland (2020) the Product Backlog is a dynamic, prioritized list that outlines what is necessary to enhance the product. It serves as the sole repository of tasks for the Scrum Team to undertake. Since SCRUM is an iterative software development methodology where the software is developed and presented to the end users over multiple sprints, the Product Backlog may change over time. Therefore, the Product Backlog written in this section is non-exhaustive.

Although the sixth topic, acids and bases was the topic that Form 4 students struggle the most in the Chemistry subject, the Mole Concept and Chemical Equation was chosen for multiple reasons. (a) Interview answers from the chemistry teachers (b) The topic was chosen as the second hardest by the students. (c) Lacking literature regarding the topic. Thus, the chosen Chemistry topics for the collaborative digital game will be taken from the third chapter of the KSSM Form 4 Chemistry subject, which is Mole Concept and Chemical Equation.

Based on the findings from Chapter 2, which highlighted the efficacy of puzzle games in teaching Chemistry topics, as well as the students' feedback indicating the need for extensive memorization of facts and formulas, the collaborative digital game will leverage aspects of the puzzle genre. Drawing inspiration from Rychkova et al. (2020), who demonstrated that immersive and interactive learning experiences can significantly enhance players' ability to visualize and remember chemical concepts, the game will be designed in a 3D virtual environment. The game will have the players assume different roles to combine different chemicals to solve puzzles, with a maximum of 4 players in a multiplayer session.

Four players is chosen as the maximum as Barkley et al. (2007) stating that groups of four to six students were more engaged. The platform used by Objective Terminal will be Windows, and all players must use the same platform to able to connect online.

The proposed collaborative digital game was planned to have players prevent spaceships from blowing up by answering questions on a terminal (hence the name, Objective Terminal). However the premise might be too violent for some girls, especially considering the gender distribution of female and male students in the questionnaire. The inclusion of violent theming might cause female players to lose engagement in interest as female players prefer non-violent aspects of gaming (Holly et. Al, 2024). The loss of interest and engagement in a collaborative setting will definitely cause frustration among other participants, which in turn obfuscates the data collected.

Objective Terminal will instead have the students maintain the excitement of a festival by collaboratively answering puzzles that will launch fireworks. Players will control a character that can move in a 3D environment, and are provided with tools that can help them solve the puzzles given to them on a terminal. These puzzles are based on the topic of the Mole Concept and Chemical Equation. The players are first given a question, and are provided with a molecule object which they can duplicate or combine them to make a new molecule. Depending on the puzzle, the molecule created by the players can be used to answer the puzzle.

The table below shows the proposed collaborative digital game's Product Backlog, listing the essential features required by the game, priority, and justification

Table 3.1: The Product Backlog of Objective Terminal

Feature	Feature priority	Justification
3D Character Movement	High	For immersive 3D movement in the virtual environment
Simple UI design	Medium	Easily understandable for players
Multiplayer Puzzle Game Manager	High	Essential for managing multiplayer game sessions.
Puzzle Questions and Answers	High	Essential game mechanic.
Molecule Object	High	Essential game mechanic. Helps Players understand molecules in an interactive manner
Molecule Dispenser	High	Essential game mechanic.
Molecule Duplicator	High	Essential game mechanic.
Molecule Combiner	High	Essential game mechanic.
Tutorial	High	To teach players how to properly play the game.
Feedback mechanisms (fireworks, scoring system)	Medium	To maintain player attention and engagement
Stylized World Environment	Medium	Essential for player immersion. Graphical quality/detail should not be taken priotiy due to time frame.
Sound and Music	Medium	Essential for player immersion
Integration of story elements	Low	Could improve player immersion in the game.
Molecule Hints	Low	Could help players visualize molecules in a detailed manner

3.2.5 Detailed Explanation of Game Mechanics

In this section, the game mechanics are explained in detail, exploring how these mechanics work to help immerse and engage the player. Figure 3.10 shows the flowchart of the game.

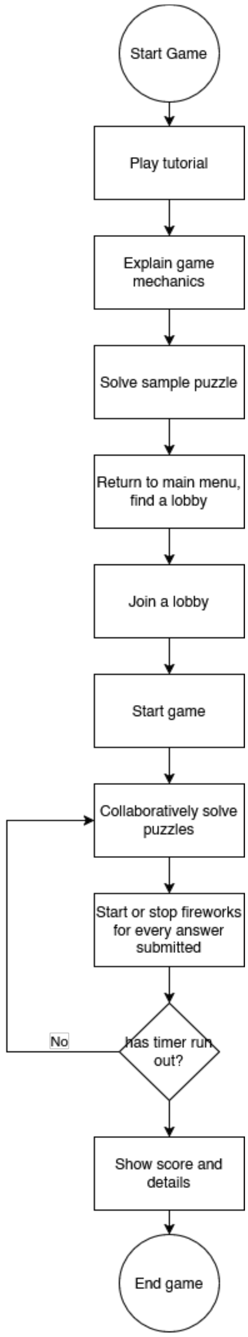

Figure 3.10: Flowchart of Objective Terminal

Objective Terminal consists of a single level where the players can perform actions to answer the puzzles. The most important objects in a level are the Molecule Dispenser, the Question Terminal and the Answer Chute. The Molecule Dispenser dispenses Molecule Objects, which are automatically dispensed when a puzzle question is given or when the player selects a button that corresponds a Molecule Object on the dispenser. The Question Terminal is where the Chemical puzzles are given to the player(s), and has a button that allows the game to start. The Answer Chute is where the players answer the puzzle by dropping the molecules that they have created. Figure 3.11 shows the layout of the level. The square highlighted in blue is the Molecule Dispenser, the one marked in green is the Question Terminal and the two rectangles in yellow are the Answer Chutes.

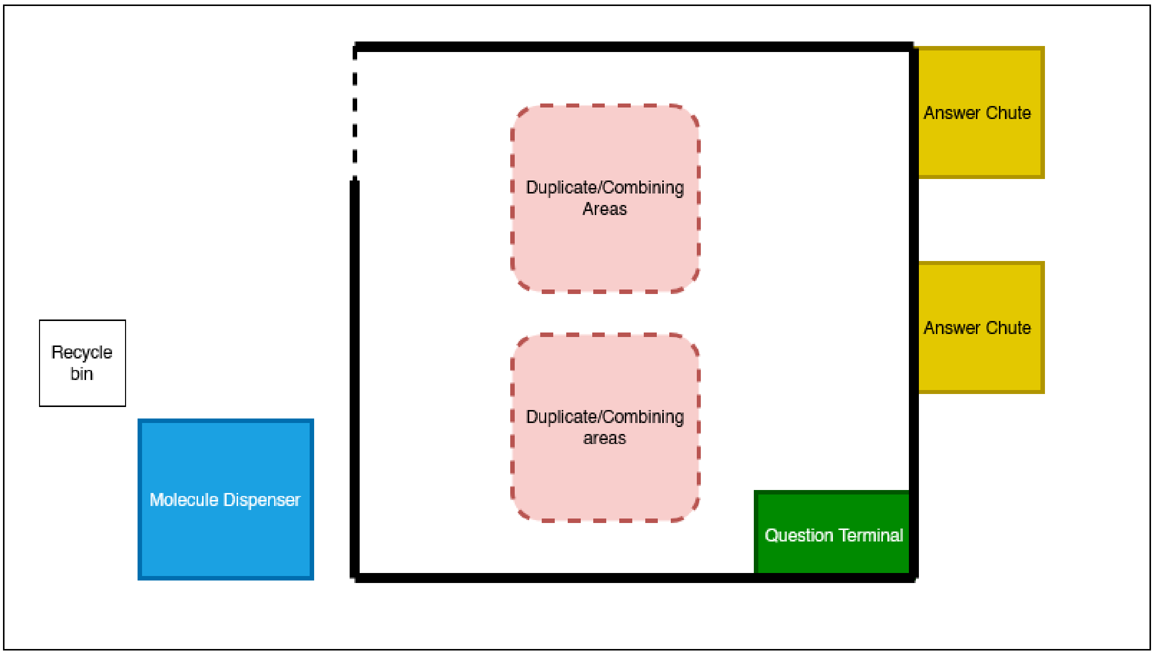

Figure 3.11: Layout of the level.

Molecule Objects are the “puzzle pieces” which can be used to solve the given puzzle. In Objective Terminal, these Molecule Objects correspond to real-life elements from the periodic table, spanning from Hydrogen to Iron, as well as any molecules created by the player. Each Molecule Object possesses unique mass values, accurately reflecting their real-life counterparts. Every Molecule Object is a spherical object with different sizes (corresponding to their mass values), with labels denoting the formula and atomic mass of the Molecule. Figure 3.12 illustrates the concept of a Molecule Object.

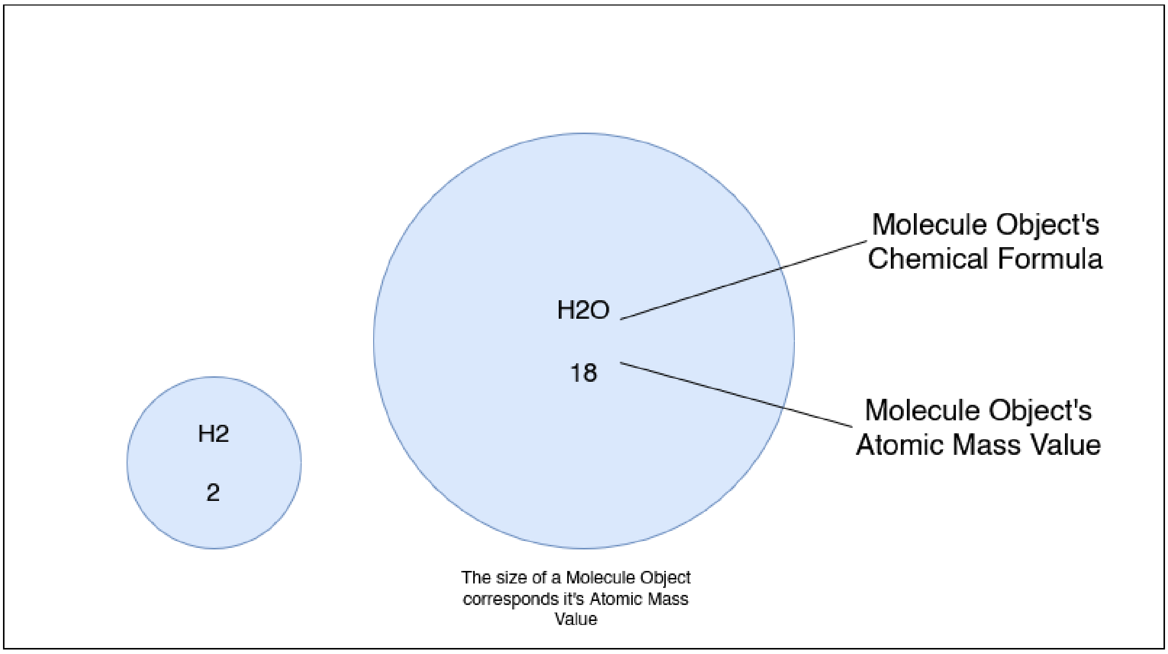

Figure 3.12: Molecule Object concept

Molecule Objects can only be manipulated using Tool Guns, which are items that the player can pick up. These tool guns, of which have two types, enable players to perform the crucial activities to solve the puzzles given. The first Tool Gun, called the Duplicator Tool enables replication of Molecule Objects. The second is a Duplicator Tool, designed to merge multiple objects together. There are only one of each tool in the single level. This is to give different roles to the players as they collaboratively solve the puzzles. This way, the game is designed for three players, and the player without a tool can carry Molecules Objects around. The game can accommodate a fourth player but they will have no roles, instead they will assume the teacher/mentor role, guiding the three players in answering the puzzles. Figure

3.13 and Figure 3.14 illustrate the concepts of the Duplicator Tool and Combiner Tool, respectively.

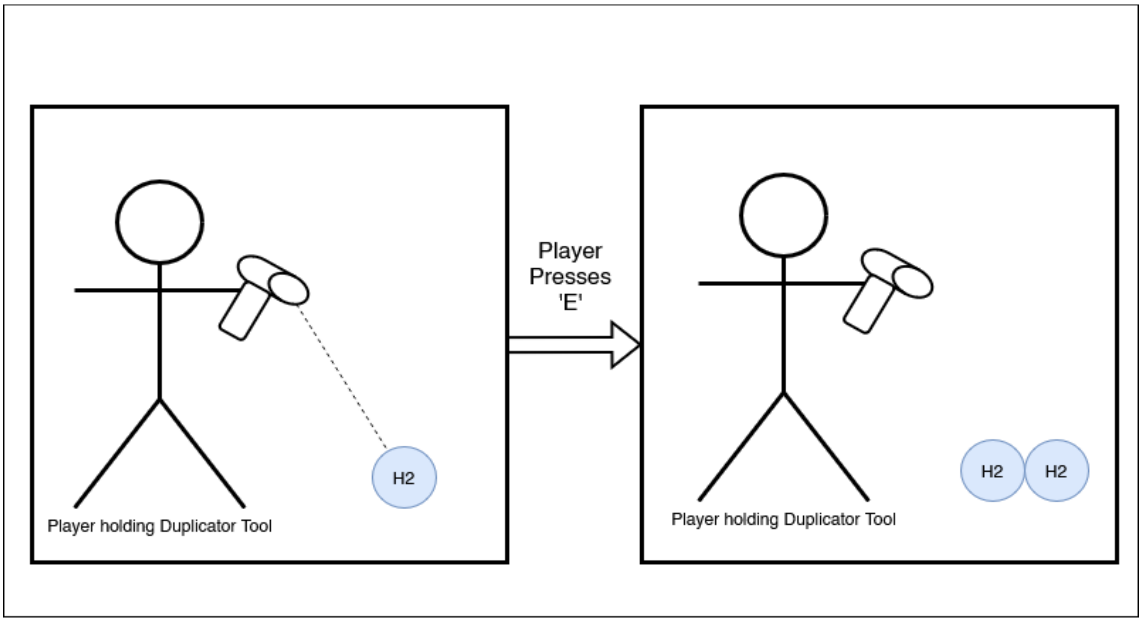

Figure 3.13: Duplicator tool concept. The player has to point to a Molecule Object and press E to duplicate it.

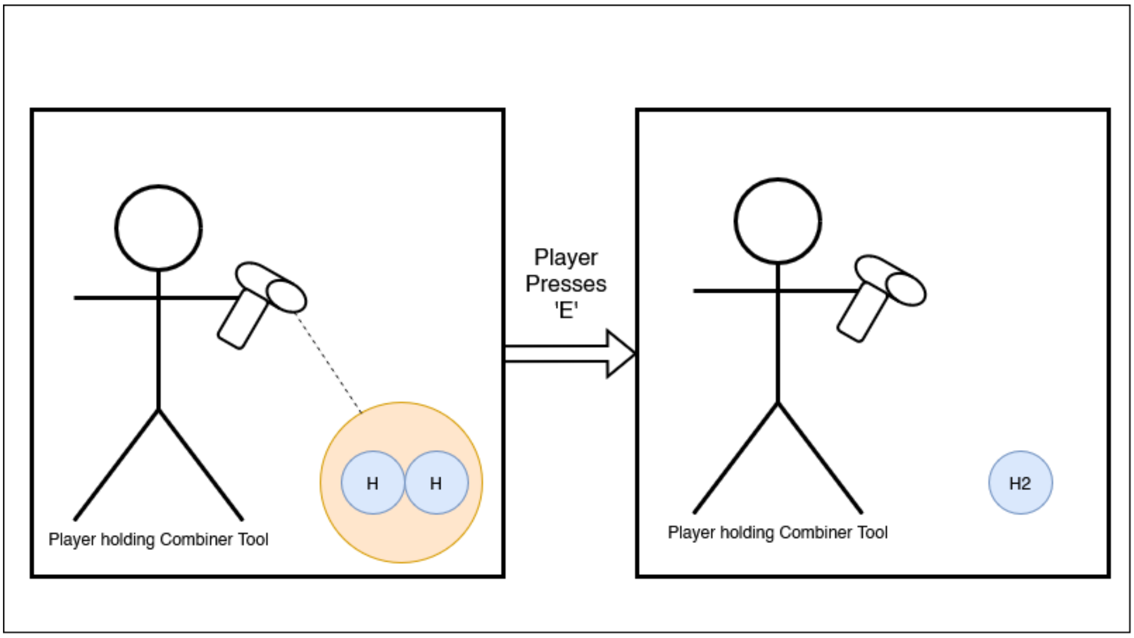

Figure 3.14: Combiner Tool Concept. The Tool creates and moves a sphere to the location the player points to. The sphere is what detects Molecule Objects to combine, therefore every desired Molecule Objects to be combined must be in the sphere to create the desired Molecule.

The puzzle-answering session (hereinafter referred to as a match) can start by any player in the level to to activate a “ready” button on the Question Terminal. Then, a timer starts, and a puzzle is randomly chosen using a Fisher-Yates shuffle algorithm, and displayed onto the Question Terminal or via the User Interface. For example, the puzzle asks Players A, B and C to balance a chemical equation, like $C3H8+O2 \rightarrow CO2+H2O$. The Question Terminal and every player’s User Interface will update to show the puzzle and potential answers as shown in Figure 3.15. Additionally, the game automatically dispenses the Molecule Objects in the equation, which are Carbon (C), Hydrogen (H) and Oxygen (O).

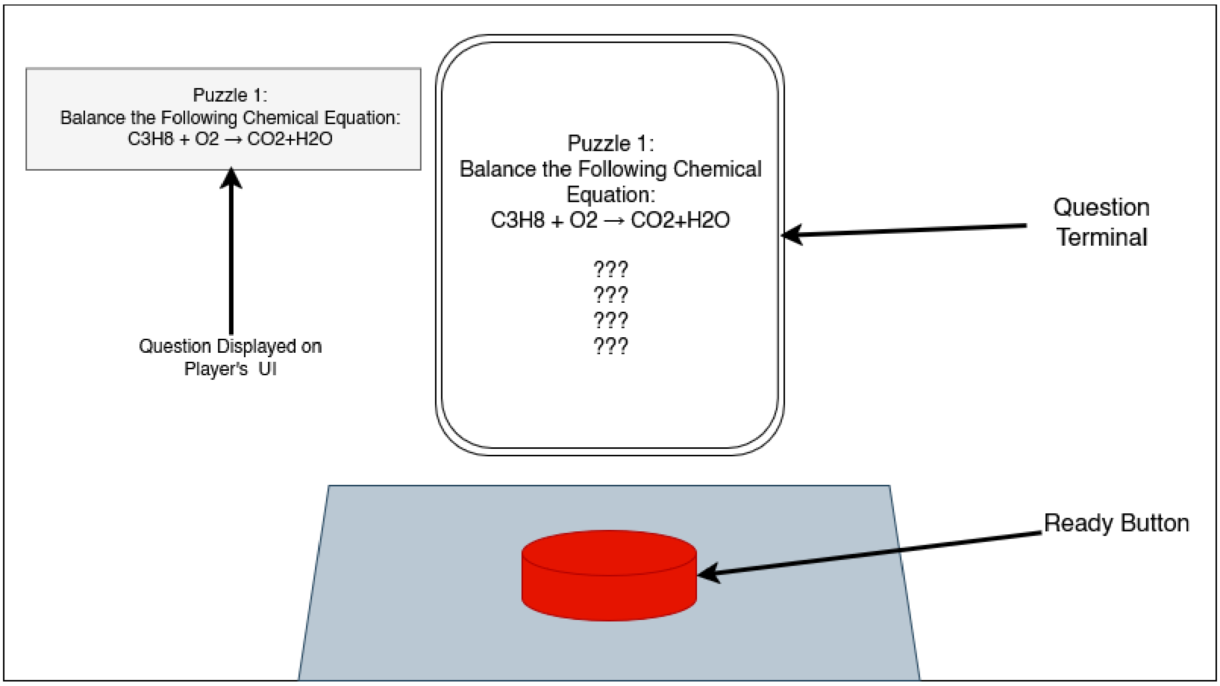

Figure 3.15: First Person Perspective of the player, showing the Player’s User Interface (UI) overlayed on the screen, the Question Terminal showing the puzzle and the four possible answers to solve the puzzle, and the Ready Button

From these three molecules, the players are to collaboratively balance the equation by duplicating and combining the molecules together. The Players then assume their roles by taking the Duplicator Tool or the Combiner Tool. In this case, Player C will use the Duplicator Tool and Player B will use the Combiner Tool while Player A will have to carry the

Molecules. The puzzle requires four molecules to be dropped into the chutes to reach a solution, which are C3H8, 5O2, 3CO2 and 4H2O. To begin, the first part of the solution, C3H8 has to be created by the players collaboratively, so Player A has to carry the Carbon Molecule from the Molecule Dispenser into the room, as shown in Figure 3.16

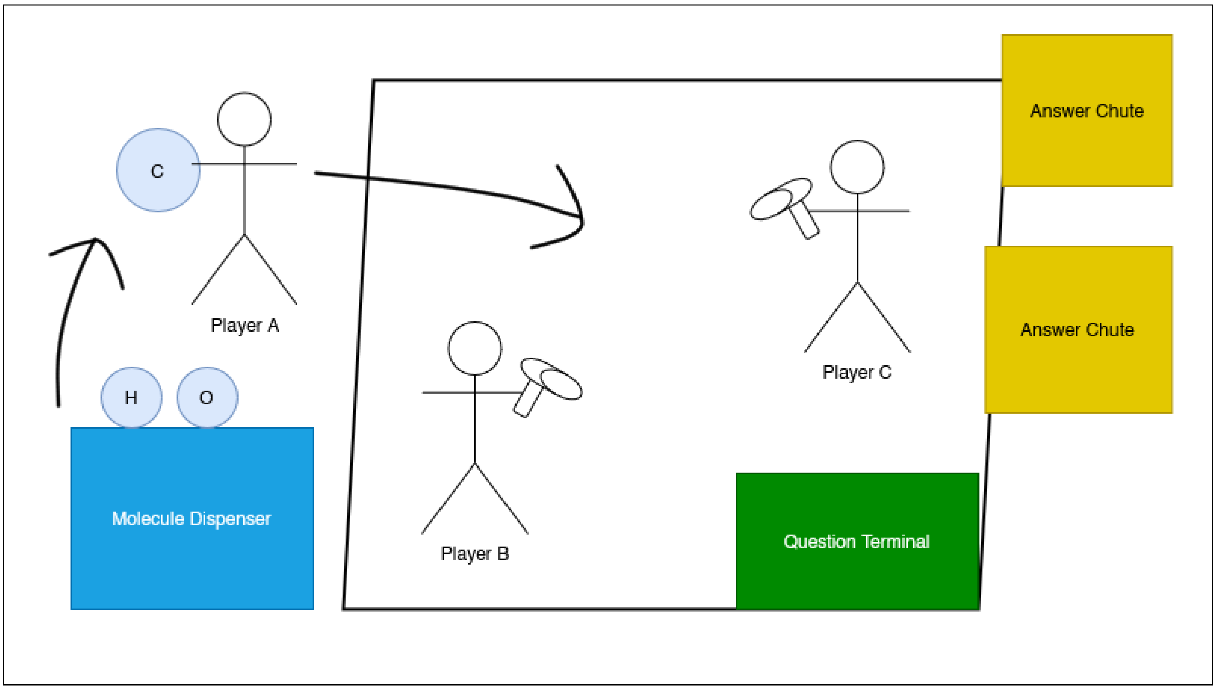

Figure 3.16: Player A carrying a Carbon Molecule into the room.

Next, Player C who is holding the Duplicator Tool has to hover over the Carbon Molecule Object and press the ‘E’ key on the keyboard two times to create two additional Carbon Molecule Objects. Figure 3.17 and Figure 3.18 shows the before and after of the scenario. The same actions will be repeated for the Hydrogen Molecule Object, Player A has to bring the Molecule into the room, and Player B Duplicates the Molecule seven times to create seven additional Hydrogen Molecule Objects.

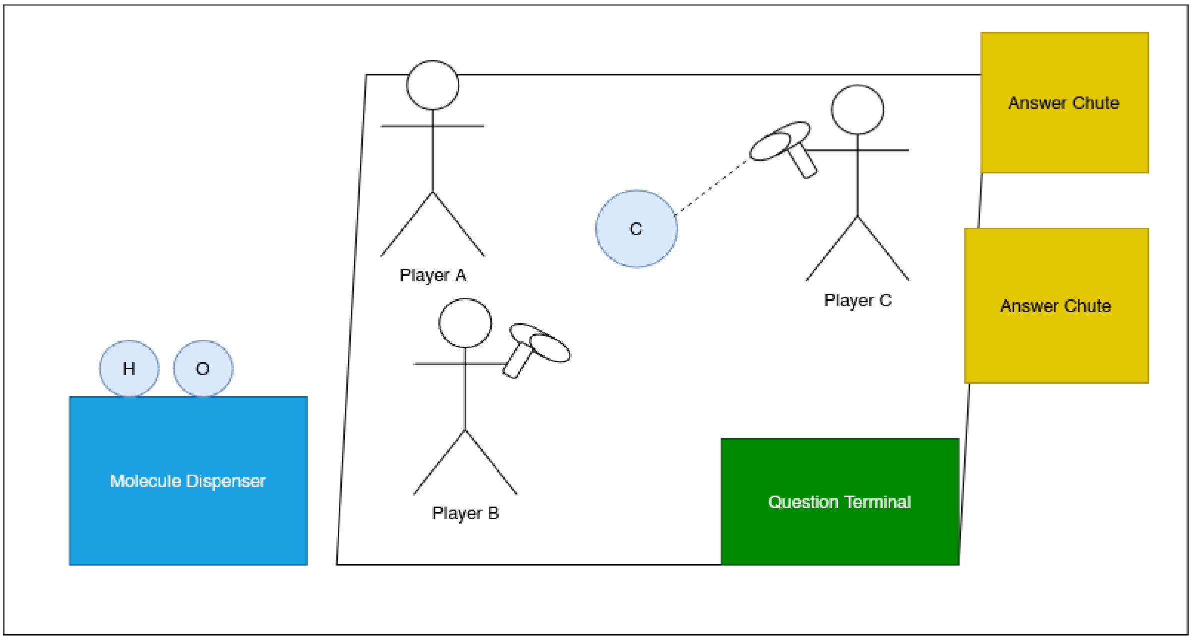

Figure 3.17: Player C hovering over the Carbon Molecule with the Duplicator Tool.

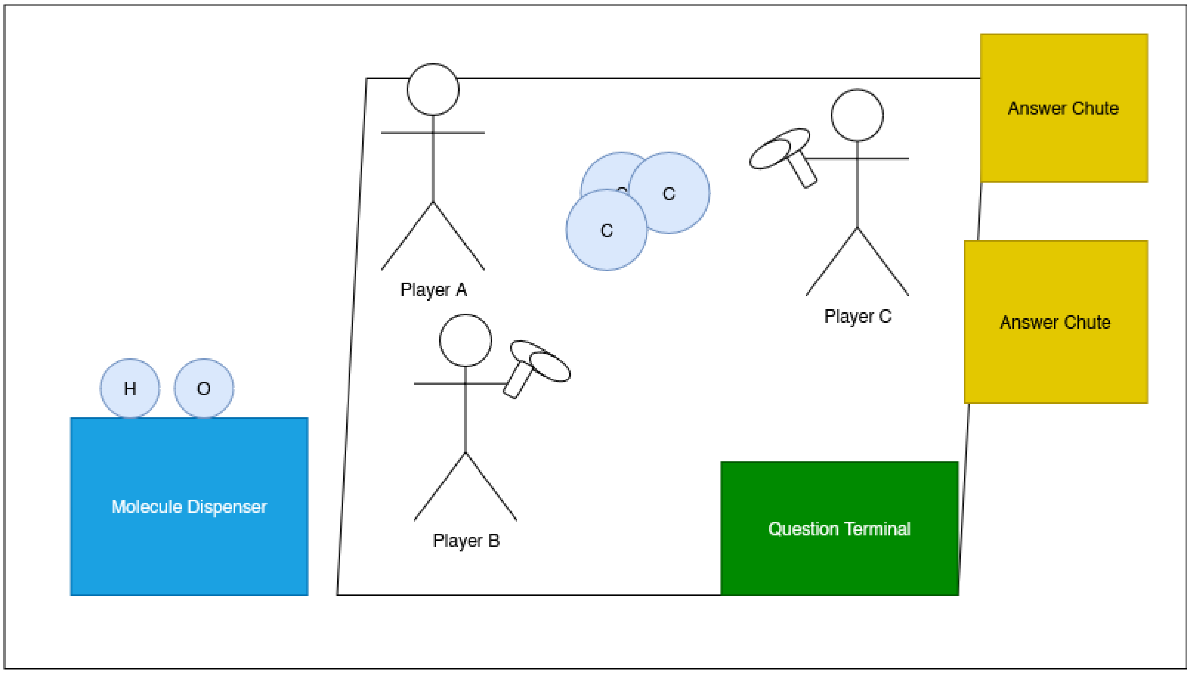

Figure 3.18: Result of duplicating the Molecule Object two times.

The number of Carbon and Hydrogen Molecule Objects satisfy the C3H8 chemical formula, but the Molecules need to be combined first. The player responsible with the

Combiner Tool, Player B will have to hover over both of the Carbon and Hydrogen Molecules, ensuring that they remain within the sphere cast by the tool to successfully combine them. Similar to the Duplicator Tool, the player has to press ‘E’ on the keyboard to combine the Molecules together. Figure 3.19 and Figure 3.20 shows the before and after of the action.

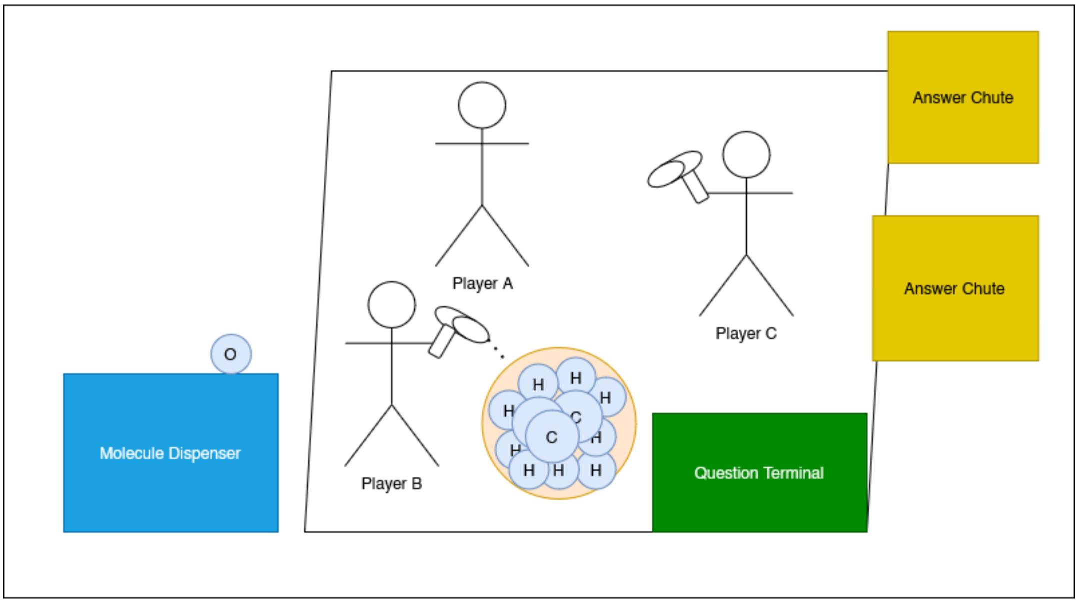

Figure 3.19: Player’s perspective of when holding a Combiner tool. The Orange circle is created by the Combiner Tool to perform the Combining action.

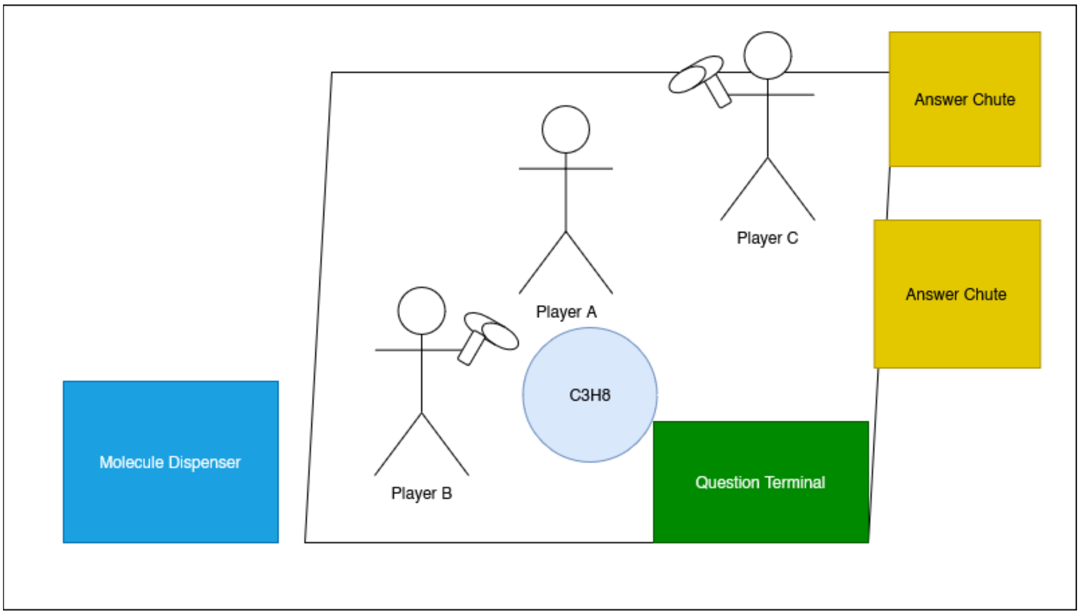

Figure 3.20: Result of Combining the collection of Molecule Objects together.

However, the first part of the question has not been properly answered yet. The player without a Duplicator Tool or Combiner Tool will have to carry the Molecule and place it into the Answer Chute. To do this, Player A needs to hover over the Answering Chute while holding the Molecule Object and press 'E' on the keyboard. Figure 3.21 visualizes the scenario.

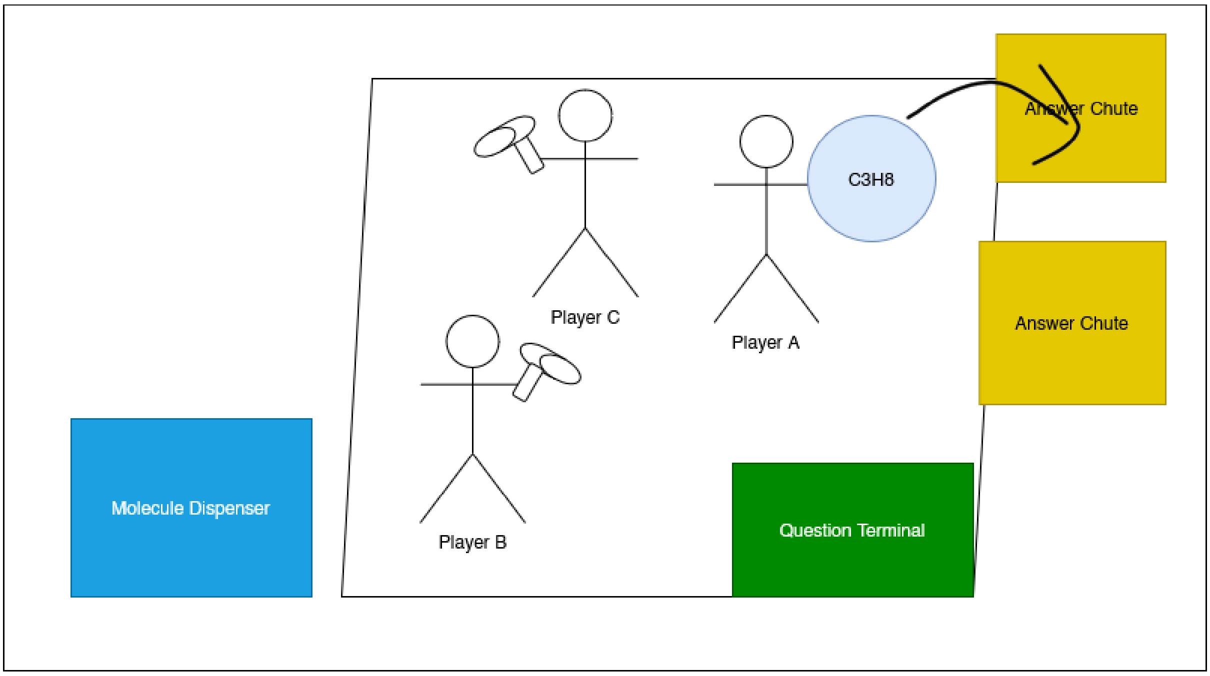

Figure 3.21: Player A placing the C3H8 Molecule into the Answer Chute to check if it is a solution for the puzzle.

If the submitted Molecule does not correspond to any of the correct solutions, both the Question Terminal and every player's User Interface will flash red to indicate an incorrect response. Conversely, if the Molecule is a match, both interfaces will update to display the provided answer. Refer to Figure 3.22 for a visual representation of this process. Although not depicted in the figure, fireworks will launch or stop launching based on answers, signalling correct or incorrect responses.

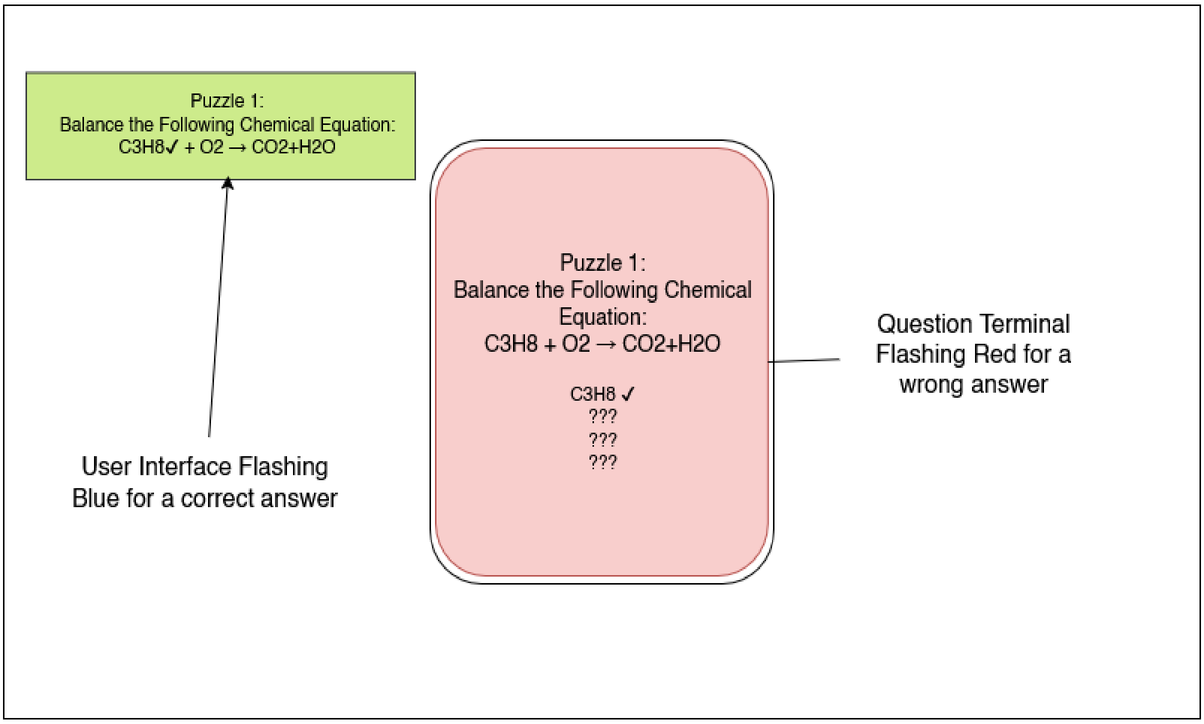

Figure 3.22: Player's perspective when looking at the Question Terminal. Both the User Interface and Question Terminal will update to show a "✔ " on a correct answer. They will flash also the same red/green colour depending on the answer, the different colour is for illustrative purposes.

A puzzle will be solved once every answer of the puzzle have been satisfied. Then, the next puzzle is given to the player, which they have to solve collaboratively. The match will end once the timer runs out, after which the game will display the Score Screen to every player. The score, the puzzles answered, and the amount of time spent on the puzzles are displayed to the player, as shown in Figure 3.23. If the player wishes to stop, they are given the option by pressing the "Return to Menu" button (shown in red). Otherwise, the player can press the Continue Playing button which will only remove the Score Screen. The ready button needs to be pressed again to start another match.

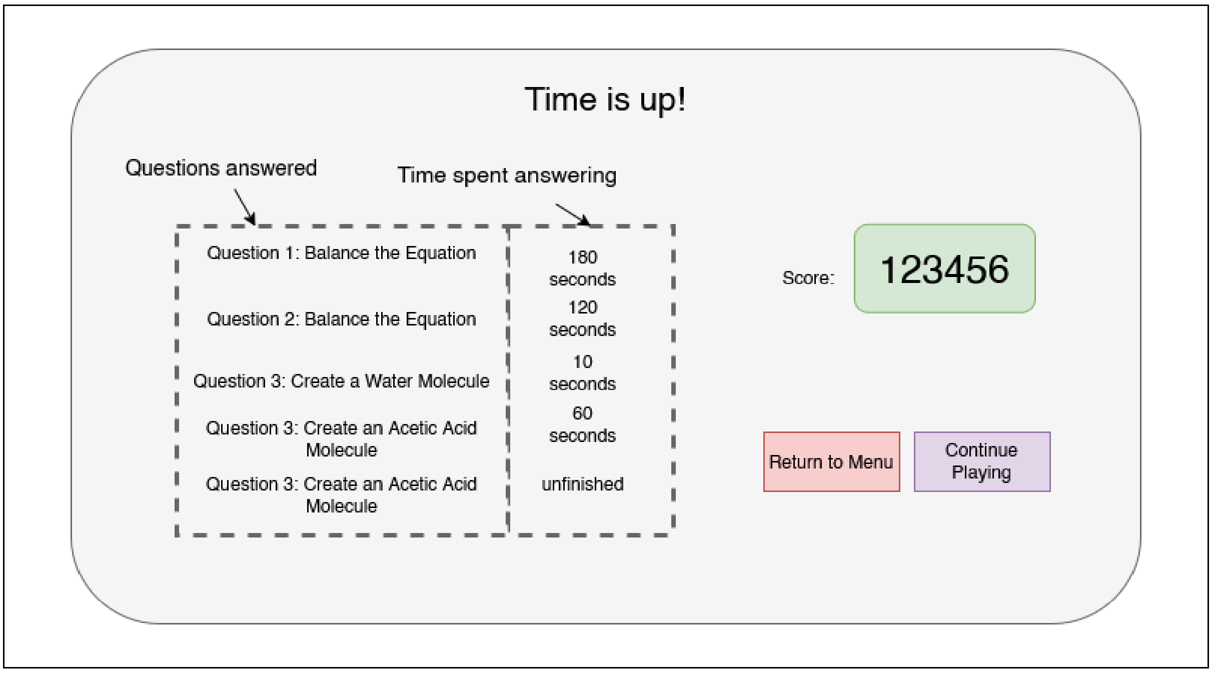

Figure 3.23: The score screen shown to every player upon the match ending. The player can see the puzzles answered, the time spent answering and score. There are also buttons to return to menu or continue playing.

3.3 Implementation

The next phase in a Sprint is the Implementation phase. The implementation phase is the longest phase of a sprint, where the features of the game is worked on based on the Sprint Backlog of the current Sprint. This step will be covered in Chapter 4: Implementation.

3.4 Sprint Review and Sprint Retrospective

The next phase of in sprint is the Sprint Review phase, followed by the Sprint Retrospective phase. The Sprint Review is where the outcomes of sprint are reviewed, which include work completed during the sprint. Depending on the review, the feature being worked on will be marked "Done" or returned to the Product Backlog for more work.

The Sprint Retrospective phase is for the members of the SCRUM Team to discuss on the highs and lows of the completed sprint. Experiences, and information are exchanged among the team to improve the quality of work. However, since the project is done alone, this phase will only have the author identifying and writing down the lessons learned during the sprint.

3.5 Definition of "Done"

Once every item in the Product Backlog is marked as "Done", or the deadline has been reached (whichever comes first), the game can be released to the players. Pre-test and post-tests and analysis of the data obtained are conducted. Chapter 5: Testing goes into detail regarding the effectiveness of conducting collaborative learning sessions in immersive 3D.

3.6 Summary

In summary, this chapter has described the SCRUM Methodology, the Sprint events, and SCRUM Artefacts in detail which will be used to guide the development of the digital collaborative game. SCRUM is an iterative methodology, that prioritizes developing working software in short cycles. Interviews and Surveys have been conducted to identify the requirements needed to develop the project. The topics of the game will be focused on the third topic of the KSSM Form 4 Chemistry subject, which is the Mole Concept and Chemical Formula. The game has been decided to be a 3D puzzle game, and detailed breakdown of game mechanics using flowcharts and storyboards have been used to illustrate the game's mechanics and premise.

Chapter 4: Implementation

4.1 Introduction

This chapter will detail the second and longest phase of a Sprint, Implementation. As SCRUM is an iterative methodology, the figures shown in this Chapter are the result of various Sprints, and thus various implementation phases. This Chapter has three steps:

1. Design related elements
2. Implement Planned Features
3. Implement Additional Features

In FYP1, Unreal Engine 5 was used as the game engine of choice as it had multiplayer development tools out of the box. However, it became increasingly clear that the game engine and the exported game required high end hardware to even launch, let alone run. Therefore the game was developed using Unity Engine with Fish Networking as the Multiplayer High Level API. This decision had improved iteration time, and hardware compatibility. The game utilizes Steam API to facilitate discovery and connecting of players to the game. Thus allowing multiplayer with selected people, which is a large factor during testing.

Most notably, the developed version of Objective Terminal now has two game modes: 1) Blitz Balance Panic, which is a the game mode described in Chapter 3, and 2) Story Mode which was requested by the author’s Supervisor midway between starting and testing the game. It has the same features as Blitz Balance Panic but now allows the players to explore the surrounding area, contains fully voiced dialogue, and the addition of another Tool Gun; the Splitter Gun. Various UX features were implemented as well, like a Molecule Inspector which allows players to see details of a Molecule Object, mouse sensitivity options to prevent nausea, and tips in the form of game textures among other things. These features are all implemented in an effort that the players quickly familiarise themselves with the game and get to collaboratively learn as fast as possible.

4.2 Design Related Elements

The 3D assets for the game were either downloaded from free online sources, or came built-into the game engine, or created by the author using Blender 4.0. The textures, if the downloaded 3D model does not come with or created by the author in Blender, were painted in Krita and Photopea. These were all created with low polygon count and texture resolution to save on performance. Audio assets were acquired online through free-to-use non-credit sources with some tweaking done using Audacity. Its important to note that all assets are solely owned by Imran Harriz bin Madzalan, and redistribution is not allowed without explicit permission.

4.3 Implement Planned Features

This section will describe the implemented game mechanics that were explored in Chapter 3. As such, this section will only describe the Blitz Balance Panic game mode and other mechanics that was outlined in Table 3.1. Section 4.4 explores the Story Mode and additional mechanics that come with.

Figure 4.1 shows an overhead view of the implemented level of Objective Terminal. Notable changes include the reduction of a duplicate/combining areas and Answer Chute count from two to one. The duplicate/combining areas had to be reduced due to game engine limitations, whereas the Answer Chute count was reduced from two to one due to UX considerations. Some minor changes include the location of the Molecule Dispenser. Additionally, below the labels on the Molecule Dispenser, there are buttons that, when pressed, will spawn Molecule Objects corresponding to those labels. Note that noble gases and some non-reactive atoms have not been implemented. The location shown in the figure is designated as the "Working Tent" and one of four explorable areas in the game.

Figure 4.1: The Working Tent.

Figure 4.2 shows two Molecule Objects of different sizes. The proposed labels on the Molecule Objects was not implemented due to performance overhead and time constraints. As designed, the Molecule Objects grow in size as the mass increases but it has a maximum value to make sure the Molecule Object fits into the Answer Chute.

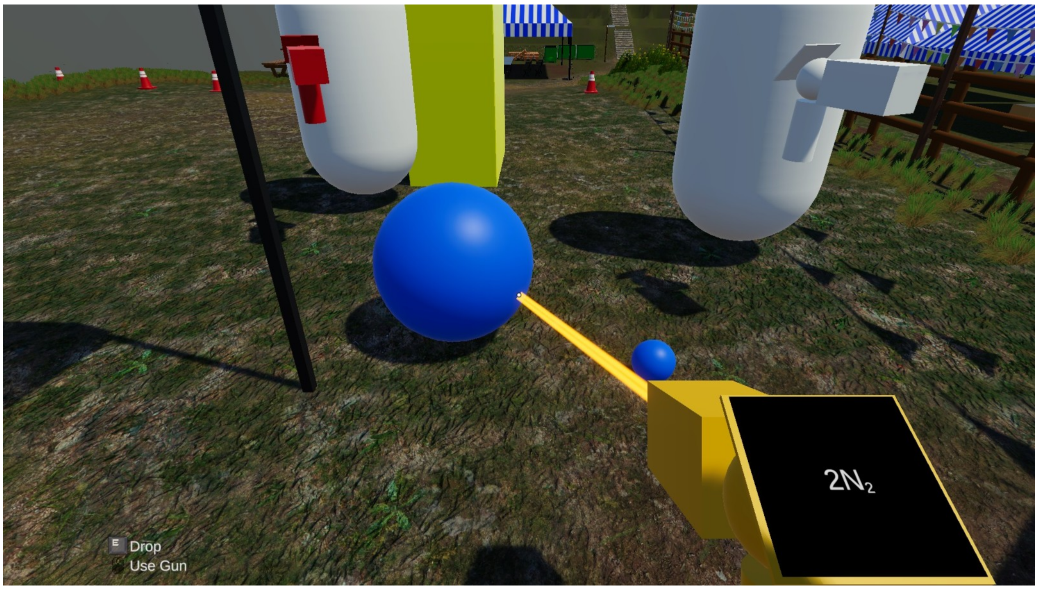

Figure 4.2: Two Molecule Objects of different size.

Figure 4.3 shows the two tool guns being held by players, demonstrating the ability for it to be picked up. The command to pick up these Tool Guns is keyboard 'E'. Note the orange sphere in the middle. It is the Scanner Sphere used by the Combiner Gun, the position of which is manipulated by where the player is pointing.

Figure 4.3: Tool Guns being held by players.

Figure 4.4 and 4.5 shows the before and after effect of using the Duplicator Gun and Combiner Gun respectively. The visual effect in Figure 4.5 is different depending on the validity of the molecule created. Instead of pressing keyboard 'E' to use the Tool Guns, it is now Left Mouse Button. Pressing E while holding a Tool Gun or Molecule Object now drops it. The interface on the tool guns is also an added feature. The Duplicator Gun's interface shows the Molecular formula of the Molecule Object being aimed at, whereas the Combiner Gun shows the number of atoms inside the Scanner Sphere.

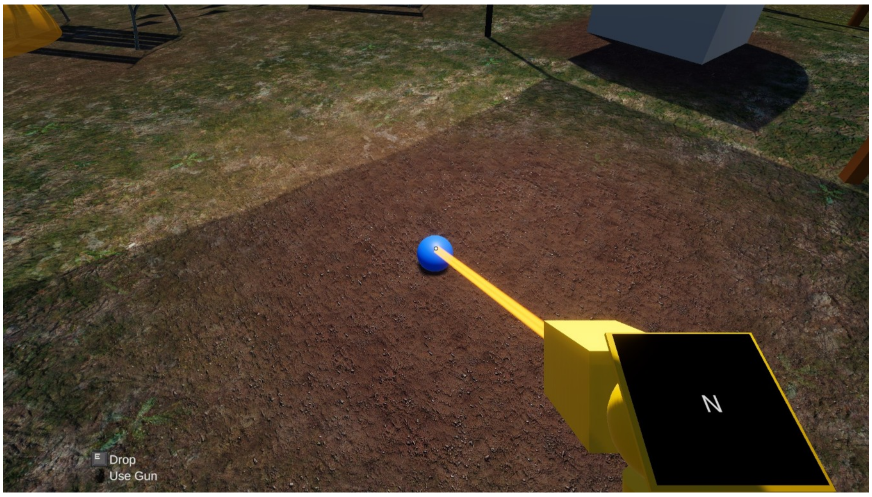

Figure 4.4:Before using the Duplicator Gun

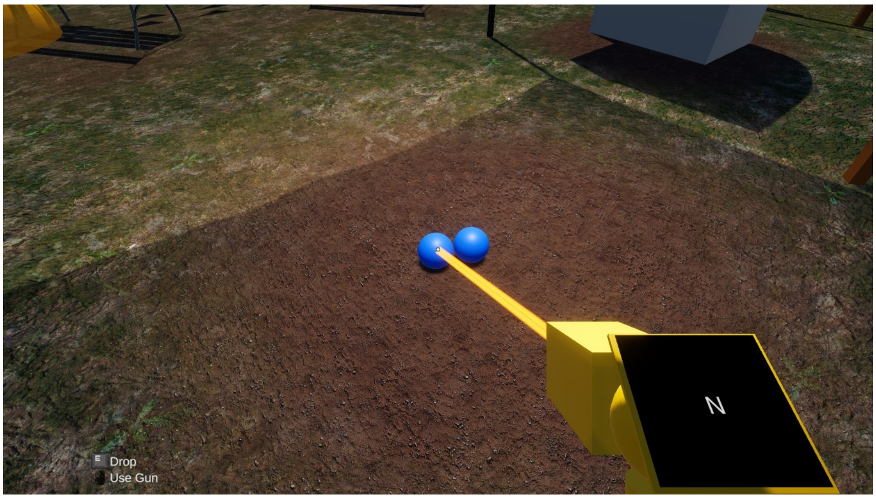

Figure 4.5: After using the Duplicator Gun

Figures 4.6 and 4.7 shows the before and after using the Combiner Gun. In Figure 4.6, all the Molecule Balls have the molecular formula NO_3. After combining all five of the Molecule Objects, a new, bigger Molecule Object appears with a stoichiometric ratio of 5. The molecule details can be inspected using the Molecule Inspector, as seen in Figure 4.7. It can be done by pressing left mouse button while aiming at a Molecule Object and not holding anything.

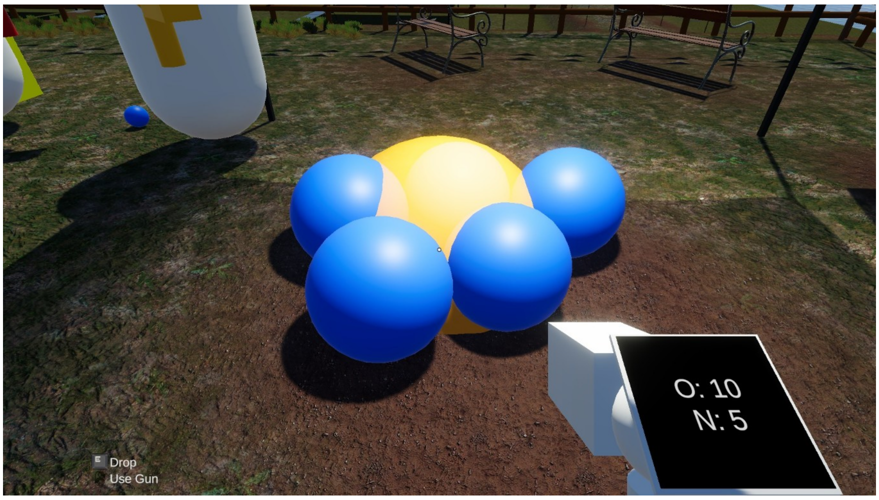

Figure 4.6: Before using the Combiner Gun

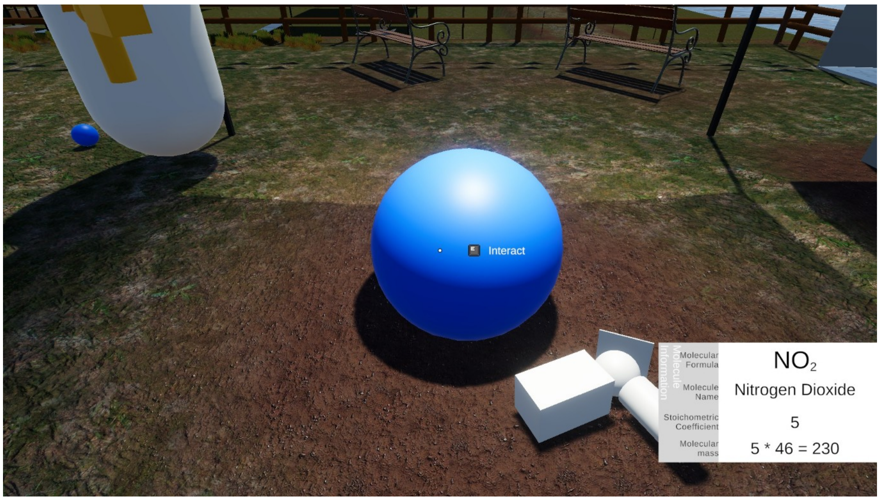

Figure 4.7: After using the Combiner Gun.

Figure 4.8 shows the result after interacting with the Question Terminal. The button to start a match is now a two small buttons, red and green. This is also due to UX considerations. The green button, which starts the match is put to the closer to the players while the red button, which stops the match is put to the far end of the table to prevent accidental interaction. The UI and Question Terminal Interface updates to show the question upon starting the match.

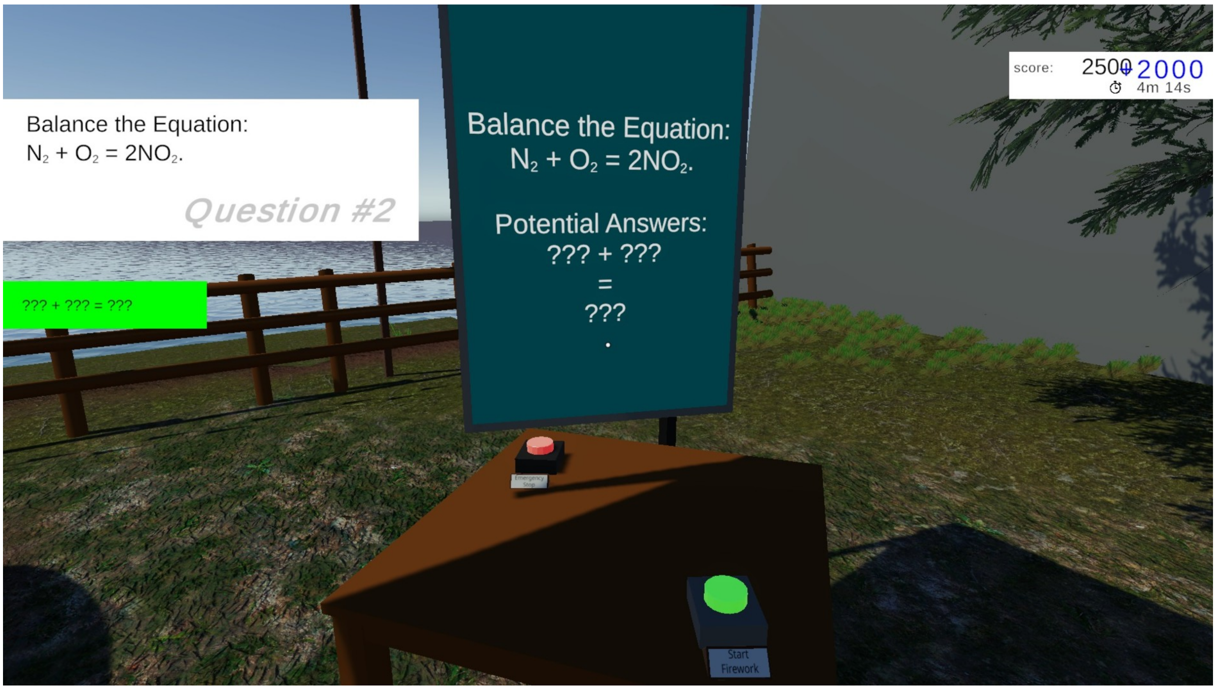

Figure 4.8: The question Terminal and the two buttons.

As planned, players are presented with a question selected at random from a predetermined set. These questions fall into two categories: general chemistry questions and balanced equation questions. General chemistry questions are straightforward, asking things like "What is the formula for an oxygen molecule?" These serve to add variety and balance to the more challenging category, which consists of balanced equation questions. As detailed in Chapter 3.3.4, balanced equation questions require multiple answers and must be solved collaboratively by the players. In total, the game includes 19 unique questions, as listed in Appendix E. During gameplay, 10 questions are randomly selected from this pool using the Fisher-Yates Shuffle algorithm and are then presented to the players in sequence.

After pressing the Start button, the players assume their roles. Players B and C take the Duplicator Gun and Combiner Gun, and Player A stands by to carry molecules. As a Balance Equation question is given, the players have to manually get the molecules needed at the Molecule Dispenser. The Puzzle given, which is $N_2 + O_2 = 2NO_2$, requires Nitrogen (N) and Oxygen (O) to solve. So player A presses the buttons labelled N and O on the dispenser, and throws one of them into the tent, as shown in Figure 4.9.

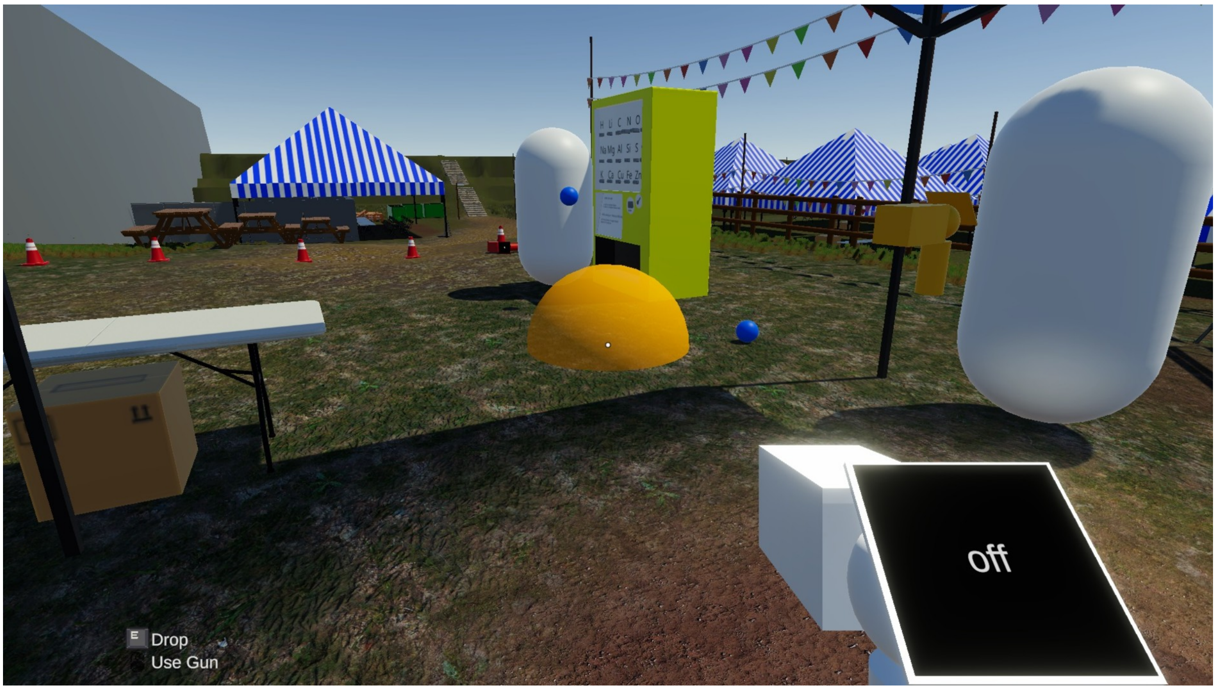

Figure 4.9: Player A (middle) holding a Molecule Object with Nitrogen.

The player holding the Duplicator Gun uses it on the Molecule Object three times to get a total of two nitrogen Molecule Objects, as seen below in Figure 4.10. The same action is repeated with the Oxygen Molecule Object, five three to get a total of four Oxygen Molecule Objects.

Figure 4.10: Player C, seen on top after duplicating the Molecule Objects

Player B holding the Combiner Gun aims at the group of Molecule Objects, and the orange Scanner Sphere moves to where the player is aiming. This is shown in Figure 4.11. Player B them presses Left Mouse Button to use the Combiner Gun, which will spawn a new Molecule Object as shown in Figure 4.12 below.

Figure 4.11: Player B about to combine the group of Molecule Objects

The newly spawned Molecule Object has a molecule formula of "NO_2" and stoichiometric coefficient of 2. The formula, name, stoichiometric ratio and mass can be inspected by pressing the Left Mouse Button while holding nothing. This will display the Molecule Inspector, as shown in Figure 4.13.

Figure 4.12:The newly created Molecule Object being Inspected.

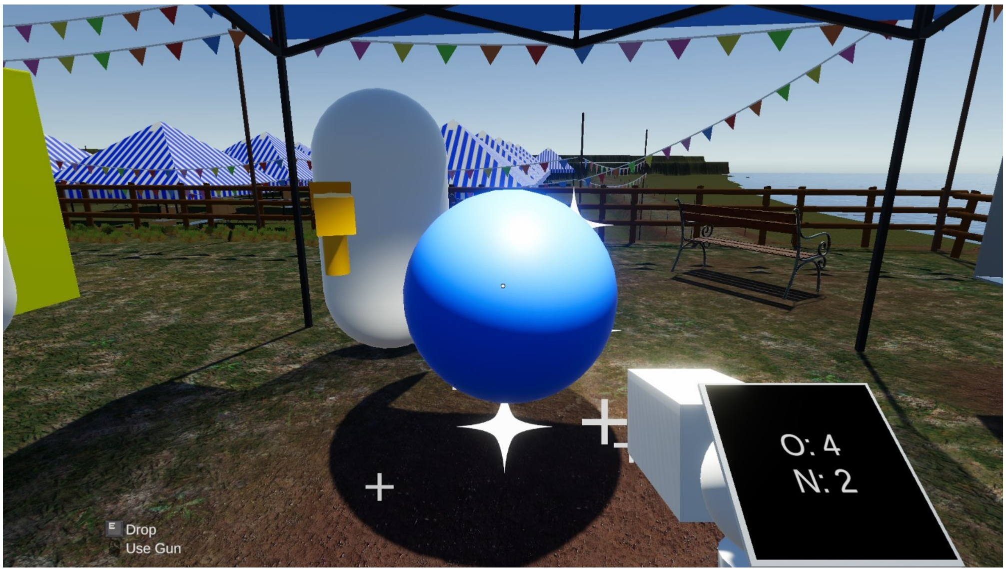

Figure 4.13: The newly spawned Molecule Object after Combining.

The solution still needs to be checked. This can be done by Player A picking up the created Molecule Object, and throwing it into the grey-colored Answer Chute. The User Interface will update, showing the answer progress as shown in Figure 4.14 below. It should be noted that unlike the planned version, the Question Terminal will not change color, and the answer progress will only show parts of the correct solution.

Figure 4.14: The User Interface after a submitting a correct answer.

Once every part of the solution have been answered, the User Interface will update to display “Correct Answer”. Although not shown in Figure 4.15 below, Fireworks are being fired in the background.

Figure4.15: The User Interface after submitting the last of the three-part puzzle.

After 5 seconds, the next puzzle is given for the players to solve. This will continue until the timer runs out, or the players have successfully answered all 10 questions, whichever comes first. When either of those cases happen, the score screen is displayed to all the players, showing the score, number of correct answers given, number of wrong answers given and number of same answers given. Figure 4.16 shows the score screen after completing a match. The table listing questions answered and time taken was not implemented due to time constraints.

Figure 4.16: Blitz Balance Panic's Score Screen.

4.4 Additional Features

This section describes the various features implemented after various sprints, design reconsiderations and feedback from various sources. Features such as the story mode, story subtitles, Splitter Gun, Mission Object and Settings Menu, are all explored in this chapter. Although outlined in Chapter 3, the Tutorial and Story Mode is explored in this section due to the feature's priority being more emphasized during FYP2.

4.4.1 Tutorial

The level used in the Tutorial is the same as every Game Mode in Objective Terminal, but has extra area blockers. This is to prevent players from missing the triggers that display Tutorial panels. The players have to read through these Tutorial panels, which then disable the area blockers, allowing the players to progress. Figure 4.17, Figure 4.18, Figure 4.19, and Figure 4.20 shows excerpts of the 4 Tutorial Panels.

Figure 4.17: General Movement Controls tutorial panel.

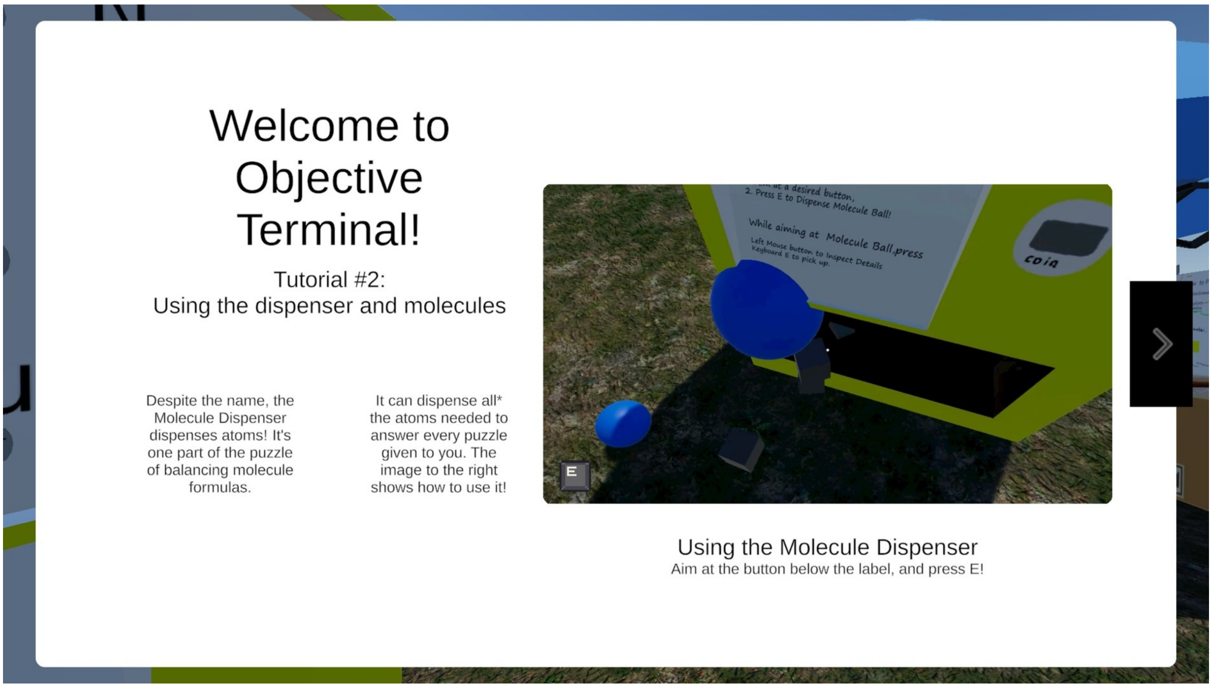

Figure 4.18: Molecule Object and Molecule Dispenser tutorial panel.

Figure 4.19: Tool Guns tutorial panel.

Figure 4.20: "How to start and play a match" tutorial panel. Note that the Heading labels are incorrectly written, it should be "Playing the game".

After reading every Tutorial Panel, the players are instructed to start the match by interacting with the Question Terminal. The game then gives a sequence of 3 questions for them to solve, which are designed to practically teach the players on playing the game. The Tutorial shares the same game controller as Story Mode. As such, it is able to display story dialogue through the use of the Story Subtitles system. Figure 4.21 shows the an example subtitle from the Tutorial.

Figure 4.21: Dialogue during the Tutorial, given through subtitles (bottom).

4.4.2 Main Menu and Settings

As described in the flowchart in Figure 3.10, the players are to return to menu and join a lobby before starting a match. Figure 4.22 shows the Main menu and the various buttons on the bottom right section of the screen. Due to feature prioritisation, the main menu was not stylized.

Figure 4.22: Main Menu of Objective Terminal

Pressing the Multiplayer button will show the Multiplayer Panel. Multiplayer can only be achieved by Local Area Connection (LAN), meaning all players have to be on the same network. The players can choose the game mode, and can start a game by pressing the green button as shown in Figure 4.23. Story Mode is the default game mode and can be switched to Blitz Balance Panic using the grey-colored dropdown button above the start button.

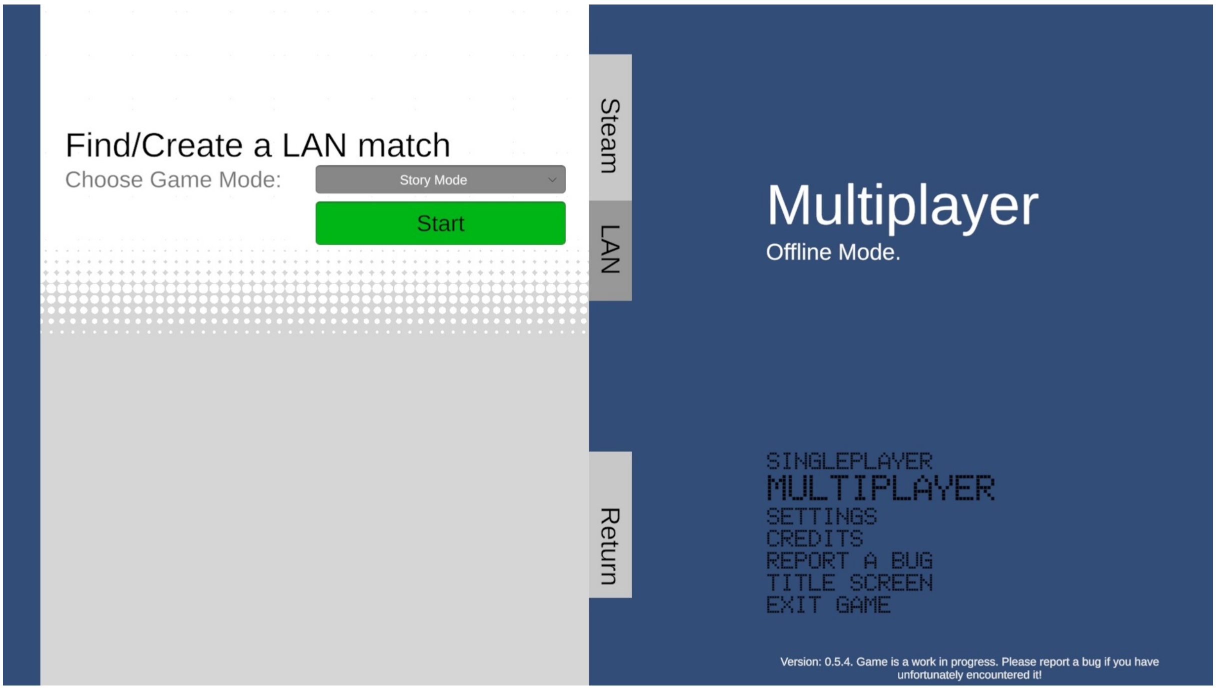

Figure 4.23: The Multiplayer panel shown after clicking the Multiplayer Button.

Upon pressing the Start Button, the scene changes to the game level, where the LAN Connect Menu is displayed. The menu provides instructions on how to connect to other players, as shown in Figure 4.24. The LAN Connect Menu includes two key buttons: one to start as a server and another to search for a server. Before connecting, players must first enter a shared secret code, similar to a password. This code ensures that only players with the same secret code can join the game. There is also a Return to Menu button in case players would like to cancel starting a multiplayer game.

Figure 4.24: The LAN Connect Menu, shown after pressing the Start button.

As long as all players use the same secret code, it does not matter if the server is started after clients begin searching. For example, players B and C may search for a server before player A, who hosts the game, starts the server. Once a computer becomes the server, it will accept connections from other players. When a connection is established, the LAN Connect Menu closes and all players are spawned into the game.

A settings panel was also added. The settings panel has 3 tabs named gameplay, audio and graphics. The gameplay tab allows changing of several accessibility options like mouse sensitivity and UI size. The audio tab controls the loudness of in-game audio and the graphics tab controls various options related to graphical quality. These tabs can be switched to by clicking the labelled buttons on the side of the settings panel. It can be accessed from the Main Menu or through the pause menu. Figure 4.25 shows the settings panel accessed through the pause menu.

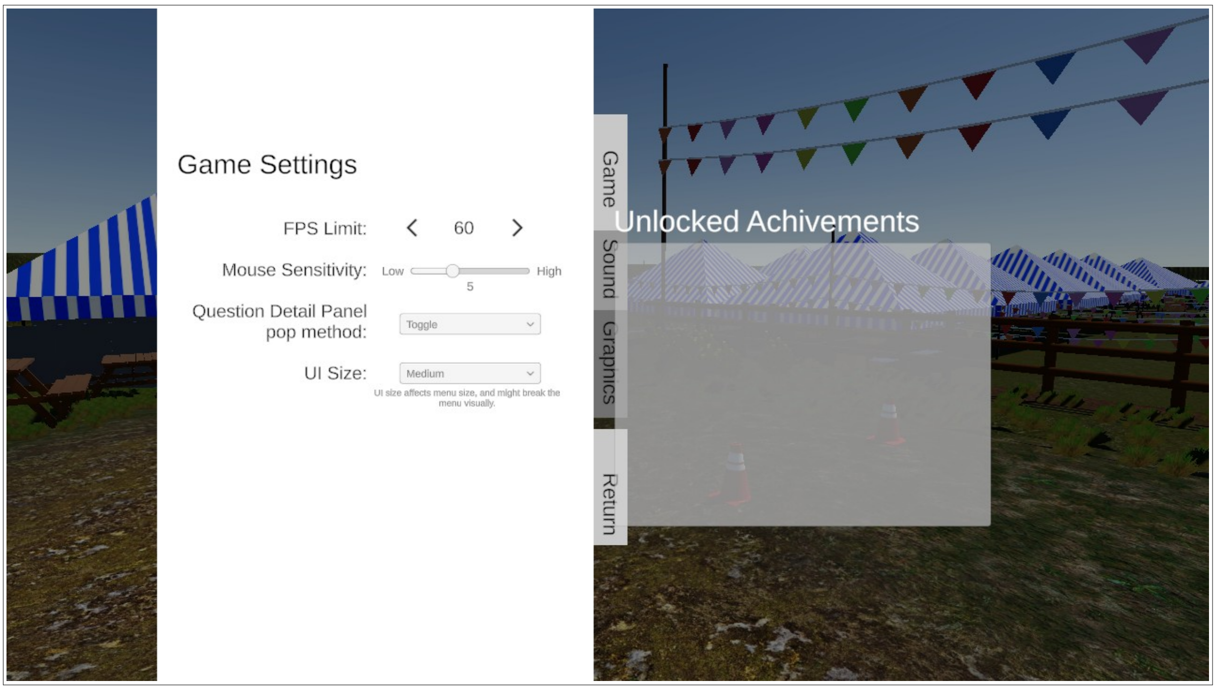

Figure 4.25: The Settings menu being accessed using the pause menu.

4.4.3 Story Mode and Related Features

With the introduction of story mode, a new tool gun called the Splitter Gun was added. This tool allows players to break Molecule Objects down into their individual atoms. To use the Splitter Gun, players have to aim at a Molecule Object and press the Left Mouse Button. The targeted Molecule Object will be destroyed, and its constituent atoms will spawn nearby as separate Molecule Objects. Figure 4.26 and Figure 4.27 shows an in game demonstration of splitting a Molecule Object with a molecule formula of $12O_2$. 24 Molecule Objects are spawned as a result.

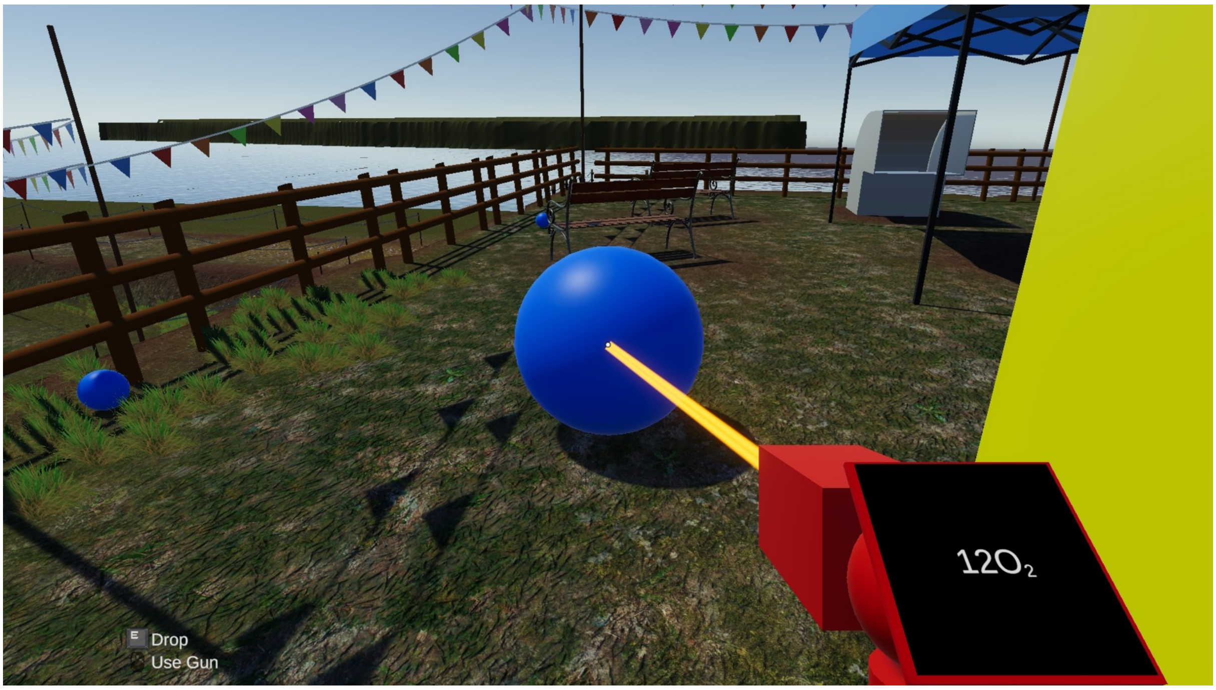

Figure 4.26: A Molecule Object containing $12O_2$ before being used by the Splitter Gun.

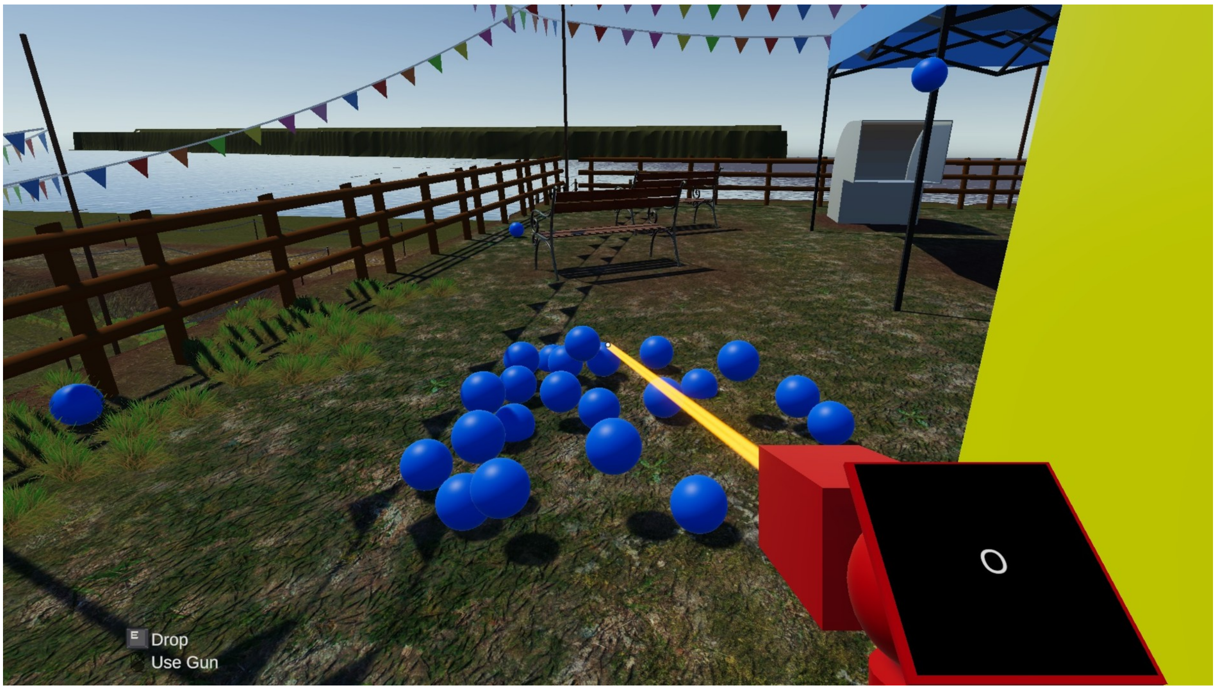

Figure 4.27: 24 new Molecule Objects being spawned after using the Splitter Gun

Instead of a game controller which randomly chooses a questions, the Story Mode required a game controller which is able to give players questions, activate/deactivate Mission Objects, deactivate area blockers and give Story Subtitles in a sequential manner. The "Sequential" game controller, and the "Mission" data structure was developed to solve this problem. Apart from code, nothing is different from the game controller. The story can be started by interacting with the green button on the Question Terminal. Missions on the other hand, store various data including the puzzle to be given, achievement data, dialogue data and area blockers to be disabled. These Missions are put in an array, the index of which is incremented after completing the given puzzle to advance to the next mission. There are 19 Missions, and once the index has reached the size of the Mission array, the Score Screen is shown and the game ends.

The core narrative of Story Mode centers around saving the upcoming Firework Festival, which is threatened by logistical problems. The player(s) are recruited by the "President" character, who tasks them with finding specific objects that each contain certain atoms. These objects are then used to create the materials necessary for the festival's fireworks. The game does not provide actual chemical formulas for making real fireworks. The story was created with help from Artificial Intelligence, specifically Perplexity Lab's Sonar-Pro. A very specific prompt was given to the AI to leverage existing assets and not bloat the game further. The "Objective Terminal Narrative" document, attached in Appendix F, contains the various prompts and the AI-generated output used to create the narrative. The story unfolds through dialogue given by the President using the Story Subtitles system (see Figure 4.21). For the full dialogue, see Appendix G.

This addition also required the level to be expanded. The Working Tent is now one of four major areas in the game. The other three being the Announcer Tent, the Riverside area, and the Bazaar area, as shown in figures 4.28, 4.29 and 4.30 respectively. Although these areas were planned in sketches during planning of the game, they were considered non-functional, visual-only elements of the game, not meant to be explored.

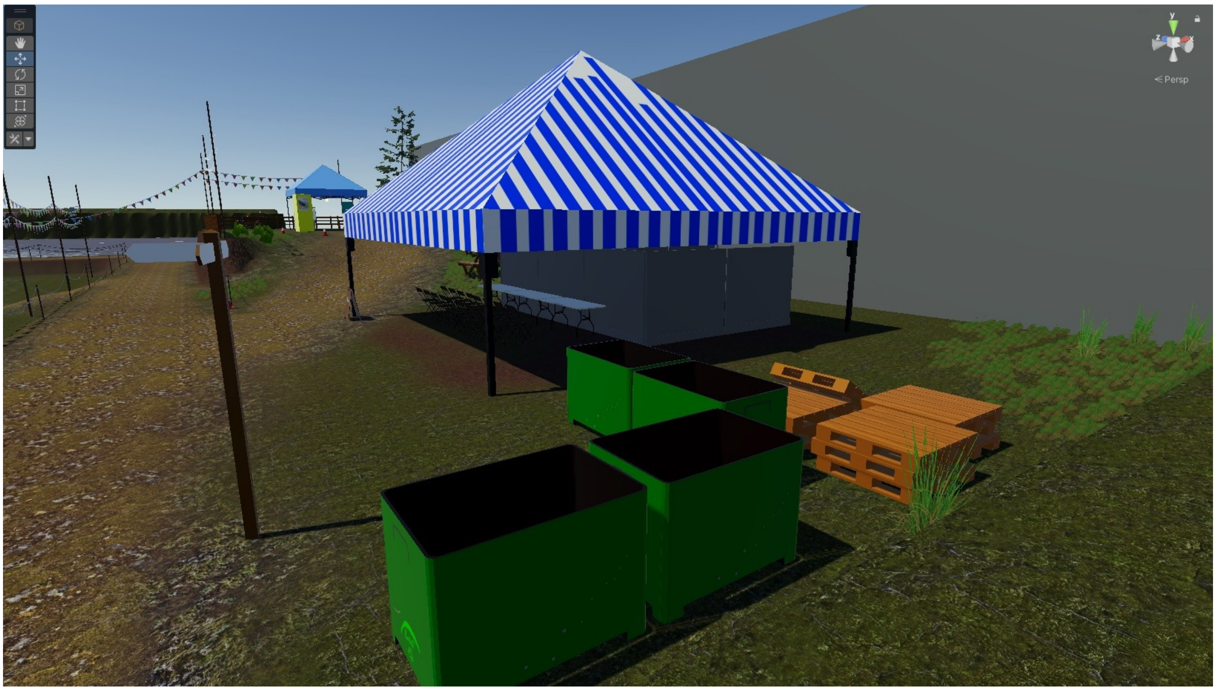

Figure 4.28: Announcer Tent, south of the Working Tent.

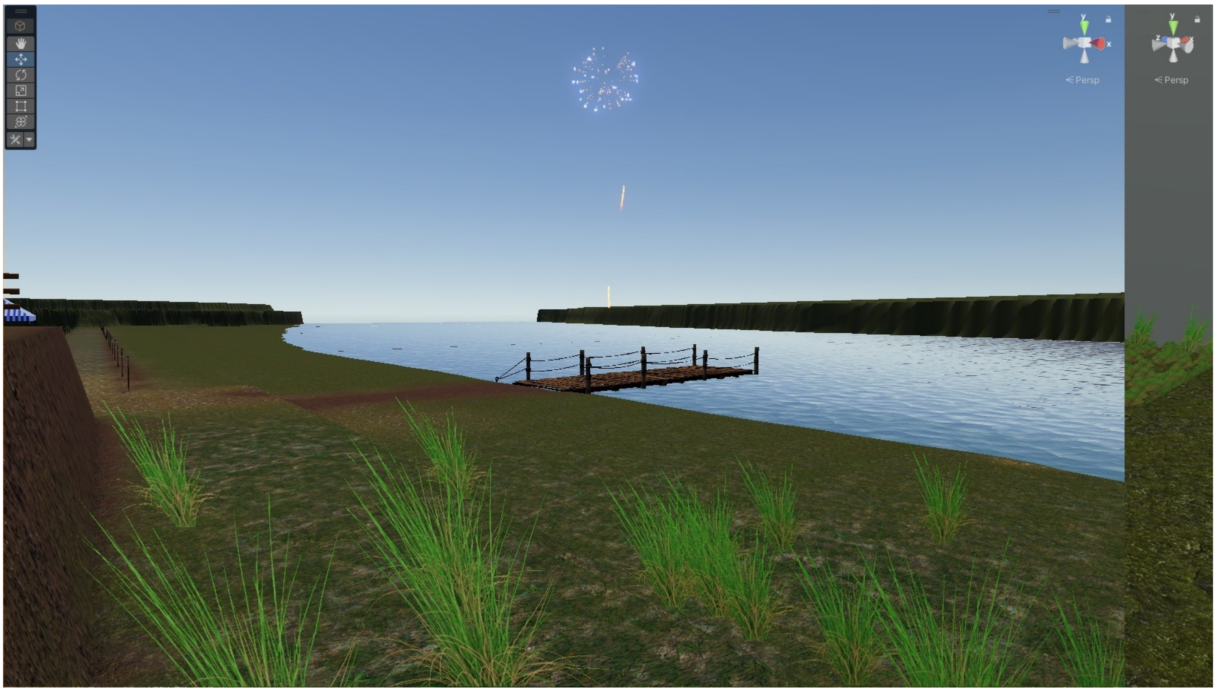

Figure 4.29: Riverside area, directly north of the Working Tent.

Figure 4.30: Bazaar Area, west of the Working Tent.

The narrative required the players to go on a treasure hunt, finding objects with certain atoms in them in these new areas. Mission Objects were developed for this reason. These are similar to Molecule Objects in a sense that it can be duplicated and split, but cannot be combined nor be picked up. These Mission Objects are placed in various places in the game world and players have to find them. Figure 4.31 shows an example Mission Object placed in the level. There are visual effects on the Mission Objects in case players fail to find them.

Figure 4.31: Mission Object and its visual effects.

Using the Duplicator gun and Splitter gun on Mission Objects will result in bonus score and large reduction in score respectively. In both cases, the constituent atoms will be dropped. However the splitting the Mission Object will temporarily destroy the Molecule Object to represent the splitting interaction. Figure 4.32 shows the before and after splitting a Mission Object, showing the sparkles, the disappearance of the Mission Object after being split, and the Molecule Objects being dropped.

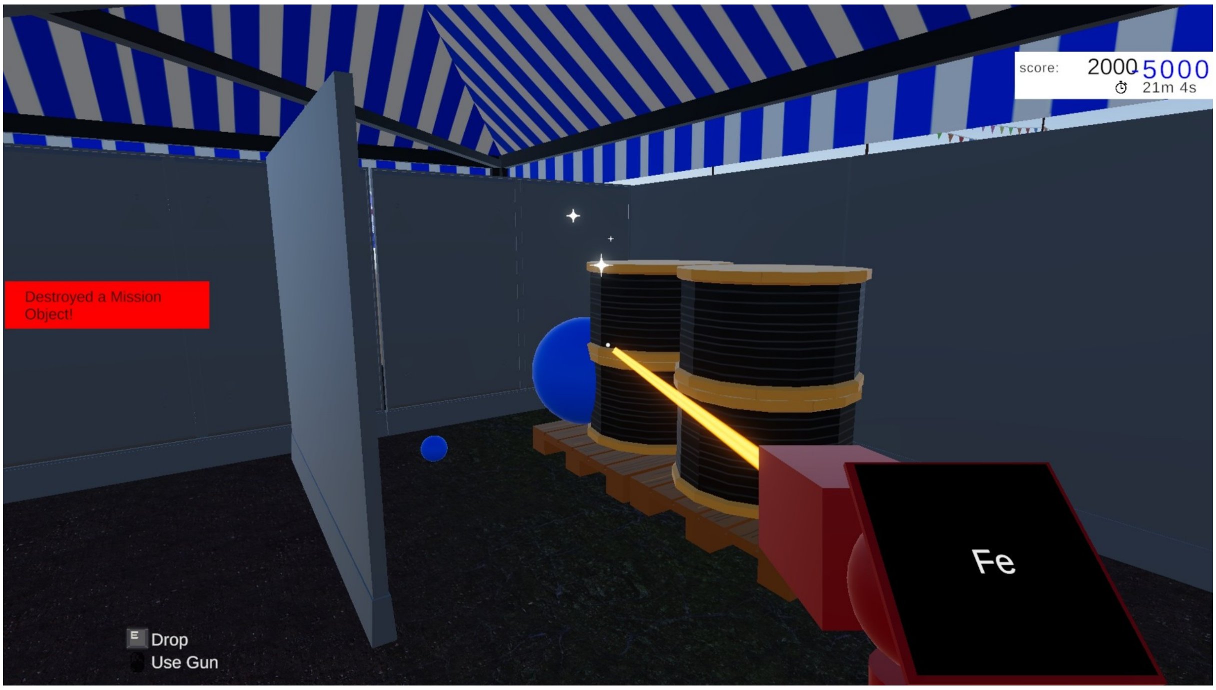

Figure 4.32: The User Interface after using the Splitter Gun on the Molecule Object and the newly spawned Molecule Objects.

In hopes to improve player engagement, an achievement system was added. These achievements are divided into two types, primary achievements and secondary achievements. Primary achievements are obtained just by going through the missions, whereas secondary achievements are obtained by meeting a certain criteria. Examples of secondary achievement are beating the story mode within 15 minutes, or not destroying any Mission Objects. Upon getting these achievements, an achievement pop-up will appear on the top right section of the screen, as shown in Figure 4.33.

To keep track of these achievements in real time, the players can enter the Pause Screen to view the obtained achievements. This is shown in Figure 4.33. The new game mode also necessitated a new Score Screen as seen in Figure 4.34, which needed to display the achievements obtained by the players. It also showed the time taken to complete the story mode in addition to the various numerical statistics in the normal score screen (Figure 4.16). The list of achievements is attached in Appendix H.

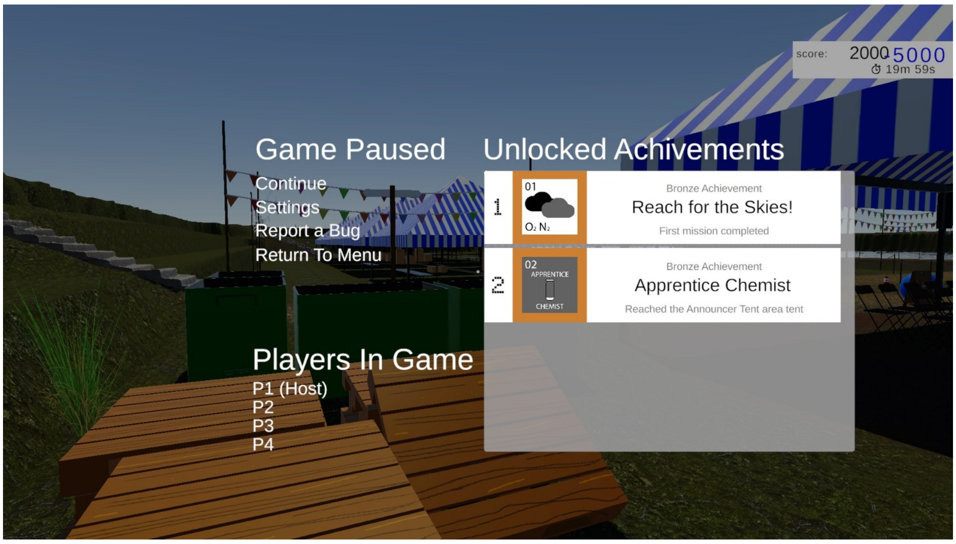

Figure 4.33: The pause screen showing the unlocked achievements.

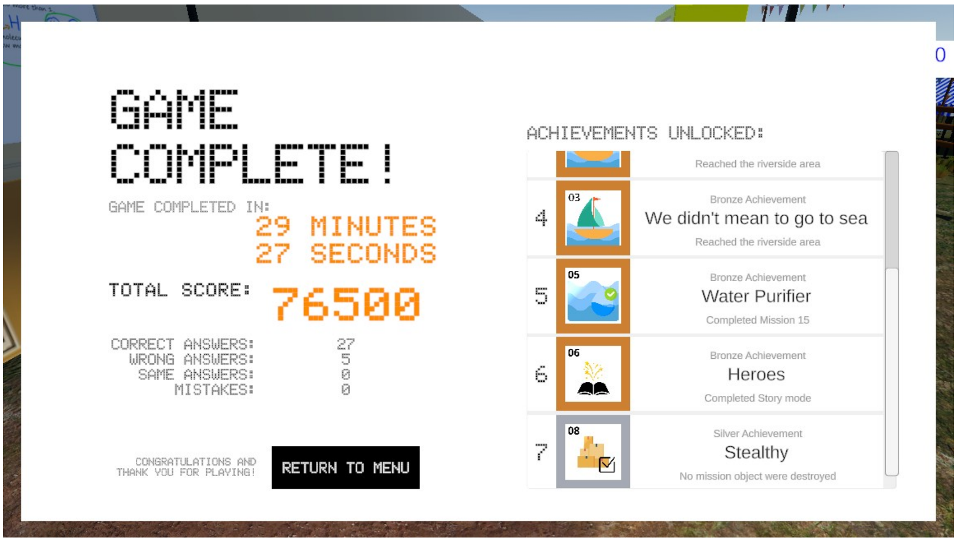

Figure 4.34: Story Mode's Score Screen.

4.5 Conclusion

In this chapter, the development process of Objective Terminal has been thoroughly examined as part of the second phase of a SCRUM sprint. During this stage, the primary game engine was changed from Unreal Engine to Unity, with Fish-Networking adopted as the Multiplayer High-Level API. The chapter provides a detailed overview of the tools and methods used to create the game's assets, along with the constraints for creating them. Furthermore, all planned game features were successfully implemented, and any modifications made to these features are discussed along with their resulting impacts. Additionally, newly introduced features that emerged during development are also described and integrated into this chapter.

Chapter 5: Testing

5.1 Introduction

This chapter will discuss the last two steps of a SCRUM Sprint, and the last step in SCRUM methodology which are:

1. Sprint Review,

2. Sprint Retrospective,

3. Definition of "Done"

During the Sprint Review, features developed in the Implementation phase are evaluated. Based on this assessment, each feature is either marked as "Done" or returned to the Product Backlog for further refinement. The Sprint Retrospective then focuses on identifying problems and improvements to enhance future sprints.

In the Definition of "Done" stage, the game is thoroughly assessed to determine if it meets the required criteria for completion. Once deemed "Done," the game is released to players, at which point pre-tests and post-tests are conducted, and the results are analyzed. The effectiveness of the game in teaching the targeted Chemistry topic is evaluated in this section, specifically through testing with Form 4 students.

It is important to note that these results represent the outcomes of several Sprint Review and Sprint Retrospective phases, reflecting SCRUM's iterative methodology. Therefore, the findings from multiple sprints have been compiled in the form of tables, to provide a comprehensive view.

5.2 Sprint Review

At the end of each Sprint, the features worked on during the Implementation phase are tested, reviewed and assessed on whether or not it is considered Done or not. During this phase, each feature is tested for its functionality, or whether it has achieved the specified metric for the sprint. This is to find any bugs and ensure it operates as intended. Table 5.1 below summarizes the cumulative outcomes of multiple Sprints and their respective Sprint Review phases.

Table 5.1: Summary of Feature tests during Sprint Review phases

Module	Function	Expected Result	Done? (Done/Not Done)
Player	Movement Input	Player movement responds to W, A, S, D key inputs.	Done
	Look Input	Camera rotates to mouse movement input.	Done
	Multiplayer Movement	Player position updates on second player’s screen as player inputs movement.	Done
User Interface	Game State: Waiting to Play	• Resets UI Values to default	Done
	Game State: Initial Start	• Initial Start Timer is shown	Done
	Game State: Dispense and Solve	• Initial Start Timer is hidden • Question Panel is shown with correct formatting • Score & Timer Panel is hidden	Done
	Game State: Puzzle Complete	• Update Score and added score values • Score & Timer Panel is shown	Done
	Game State: Match End	• Show the Score Screen	Done
	Molecule Hints	• Shows Molecule Data with correct	Done
Duplicator Gun	Pick Up	• Pressing keyboard E while aiming at the Duplicator Gun picks it up	Done
	Drop Gun	• Pressing keyboard E while holding Duplicator Gun drops it.	Done
	Use – Duplicate Molecule	• Pressing Left Mouse button while aiming at a Molecule Object duplicates it. • Success sound is played.	Done

Module	Function	Expected Result	Done? (Done/Not Done)
Combiner Gun	Pick Up	• Pressing keyboard E while aiming at the Duplicator Gun picks it up	Done
	Drop Gun	• Pressing keyboard E while holding Duplicator Gun drops it.	Done
	Use – Combine Molecule Success	• Pressing Left Mouse button while aiming at a group of Molecule Object combines it. • A “Success” visual effect is shown. • A Molecule Object with a valid name is spawned. • Success sound is played.	Done
	Use – Combine Molecule Fail	• Pressing Left Mouse button while aiming at a group of Molecule Object combines it. • A “fail” visual effect is shown • A Molecule Object with a “???” name is spawned. • Failure sound is played.	Done
Splitter Gun	Pick Up	• Pressing keyboard E while aiming at the Duplicator Gun picks it up	Done
	Drop Gun	• Pressing keyboard E while holding Duplicator Gun drops it.	Done
	Use – Split Molecule Success	• Pressing Left Mouse button while aiming at a Molecule Object with more than one atom in it destroys it. • Multiple other Molecule Object representing the constituent atoms are spawned. • Success sound is played.	Done
	Use – Split Molecule Fail	• Pressing Left Mouse button while aiming at a Molecule Object with only 1 atom in it does nothing.	Done

Module	Function	Expected Result	Done? (Done/Not Done)
		• Failure sound is played	
Game Controller – Blitz Balance Panic Game Mode	Game State – Waiting to Play	• Reset Game Timer to 0. • Stop Fireworks. • Disable Answer Chute.	Done
	Game State – Initial Start	• Start Initial Start Timer. • Switch to Game State – Dispense and Solve. • Shuffle Questions.	Done
	Game State – Dispense and Solve	• Give Question to players. • Activate and Give Question to Answer Chute. • Update UI. • Update Question Terminal Screen.	Done
	Game State – Puzzle Complete	• Give Score. • Fire Fireworks for 3 seconds. • Disable Answer Chute. • Return to Dispense and Solve after 5 seconds. • Move to Match End if timer is less than 10 seconds.	Done
	Game State – Match End	• Show Score Screen • Move to Game State: Initial Start after 15 seconds. • Return to menu if button is pressed.	Done
"Sequential" Game Controller – Story game Mode	Sequence Change – Story Subtitle	• Retrieve and give story data from Mission List to Story Subtitle Manager.	Done
	Sequence Change – Question	• Retrieve and give Question data from Mission List to Answer Chute, Question Terminal, and UI.	Done

Module	**Function**	**Expected Result**	**Done? (Done/Not Done)**
	Sequence Change – Achievement	• Retrieve associated Achievement from Achievement componenent by index retrieved from Mission Data, • Update UI.	Done
	Sequence Change – Area Blocker	• Destroy associated Area Blocker by index retrieved from Mission Data.	Done
	Sequence Change – Story End	• Show Score Screen Upon end of Mission List.	Done
Firework Controller	Fire Normal Firework	• Fire Firework for 3 seconds.	Done
Molecule Object	Pick Up	• Player 1 aims at Molecule Object and presses Keyboard E, • Player 1 picks up Molecule Object, • Player 2 sees the Molecule Object being held by Player 1	Done
	Throw	• Player 1 is holding Molecule Object and presses Left Mouse Button, • Player 1 is no longer holding Molecule Object, • Molecule Object is thrown vertically and horizontally • Player 2 sees change.	Done
	Drop	• Player 1 is holding Molecule Object and presses Keyboard E, • Player 1 is no longer holding Molecule Object. • Molecule Object is dropped. • Player 2 sees change	Done
	Multiplayer Physics Movement	• Player 1 throws Molecule Object towards a group of Molecule Object • Movement of Molecule Objects is the same in both Player 1 and	Done

Module	Function	Expected Result	Done? (Done/Not Done)
		Player 2	
	Multiplayer Spawning	• Molecule Object is spawned with the correct data • Both Player 1 and Player 2 inspects the spawned Molecule Object • Molecule data is the same on both players	Done
	Multiplayer Despawning	• Molecule Object is thrown in Answer Chute or is thrown in the Recycle Bin or is Combined • Molecule Object disappears from view • Molecule Object data is reset to default	Done
Mission Object	Duplicated	• Player 1 uses Duplicator Gun at Mission Object. • Player 1 and 2 sees the spawned Molecule Objects with the correct data • Score is added	Done
	Splitted	• Player 1 uses Splitter Gun at Mission Object. • Player 1 and 2 sees the spawned Molecule Objects with the correct data • Score is deducted	Done
Molecule Dispenser	Spawn Molecule on Interact	• Spawns a Molecule Object at the set position with the correct data	Done
Answer Chute	Answer Check – Chute inactive	• Destroy Molecule Object	Done
	Answer Check – Correct Answer	• UI is updated • Score is Added	Done

Module	**Function**	**Expected Result**	**Done? (Done/Not Done)**
		• Change Game State to “Puzzle Solved” • Correct Answers integer is incremented	
	Answer Check – Answer in Progress	• UI shows updated answer status • Score is Added	Done
	Answer Check – Same Answer	• UI shows same answer notice • Same answer integer is incremented	Done
	Answer Check – Wrong Answer	• UI shows wrong answer notice • Wrong answer integer is incremented	Done
Question Terminal	Start Match	• Interact with green button. • Enables Answer Chute, starts timer. • Changes Game State to “Initial Start” if Game Controller. • Changes Game Sequence to 0 if “Sequential” Game Controller.	Done
	Stop Match	• Interact with red button. • Disables Answer Chute, resets score to 0, resets timer to 0. • Change Match state to “Waiting”	Done
	Update Terminal Screen	• Update Terminal Screen with current Question upon Match State “Dispense and Solve”	Done
Menu	Singleplayer Button	• Shows the Singleplayer Panel	Done
	Change Scene	• Changes scene to correctly labelled scene	Done
	Multiplayer Button	• Shows the Singleplayer Panel	Done
	Change Game Mode	• Dropdown changes and sets the target Game Mode	Done
	Start LAN Match	• Changes the scene according to the target Game Mode	Done

Module	Function	Expected Result	Done? (Done/Not Done)
Settings Panel	Settings Button	• Shows the Settings Panel	Done
	Credits Button	• Shows the Credits Panel	Done
	Report a Bug Button	• Opens the Bug Report form in the Player's default browser	Done
	Quit Game Button	• Closes the game	Done
	Change Mouse Sensitivity	• Changes and saves mouse sensitivity data. • Updates player's mouse sensitivity if in-game.	Done
	Change User Interface size	• Changes, saves and updates UI Size data. • Updates game's UI size.	Done
	Change Screen Resolution	• Changes, saves and updates Screen Resolution data. • Updates game's screen resolution .	Done
	Change Window Mode	• Changes, saves and updates Window Mode data. • Updates game's window mode.	Done
	Change Frame Rate Limit	• Changes, saves and updates Frame Rate Limit data. • Updates game's frame rate limit.	Done
	Change Texture Quality	• Changes, saves and updates Frame Rate Limit data. • Updates game's frame rate limit.	Done
	Change Render Scale	• Changes, saves and updates Frame Rate Limit data. • Updates game's frame rate limit.	Done
	Change Quality Level	• Changes, saves and updates Quality Level data. • Updates game's Quality Level setting.	
	Change Anti Aliasing	• Changes, saves and updates Anti Aliasing data.	Done

Module	**Function**	**Expected Result**	**Done? (Done/Not Done)**
	Setting	• Updates game's Anti-Aliasing setting.	
	Change Main Volume Setting	• Changes, saves and updates Anti Aliasing data. • Updates game's overall main volume.	Done
	Mute Sounds Button	• Changes, saves and updates Anti Aliasing data. • Mutes or unmutes the game.	Done
	Change Sound Effects volume	• Changes, saves and updates Anti Aliasing data. • Updates game's Sound Effects volume.	Done
	Change Question Panel Pop Method	• Changes, saves and updates the player's preferred Question Panel Pop Method data. • Updates player's Question Panel pop method.	Done
LAN Connect Menu	Start as Server Button	• Advertise the computer as server with a secret code. • Disables button if secret code is more than 10 characters long. • Disables button upon pressing.	Done
	Find a Server Button	• Finds a computer advertizing as server with a secret code. • Connects to the server if secret code is the same. • Disables button if secret code is more than 10 characters long. • Disables button upon pressing.	Done
	Return to Menu Button	• Returns to Menu	Done
In-Game Pause Menu	Continue Button	• Disables the Pause Menu	Done
	Settings	• Shows the Settings Menu	Done
	Report a Bug	• Opens the Bug Report form in the Player's default browser	Done
	Return to Menu	• Returns to menu	Done

Module	Function	Expected Result	Done? (Done/Not Done)
Score Screen	Achievement Panel	• Achievement Panel updates with the correct achievement.	Done
	Show Time Taken	• Calculates and shows the time taken to finish	Done
	Show Final Score	• Calculates and shows the final score	Done
	Show Score Details	• Shows the score details (correct answer, wrong answer, same answer)	Done
	Return to Menu button	• Returns to menu	Done
	Continue Playing Button	• Disables the Score screen	Done

5.3 Sprint Retrospective

Table 5.2 below presents a comprehensive record of Sprint Retrospectives, as documented by the author in his notebook after each Sprint throughout the project's development. It details the start and end dates for each Sprint, outlines the Sprint goals, indicates whether those goals were achieved, and highlights any challenges encountered along with proposed solutions to address these issues in future Sprints.

Table 5.2:Compilation of Sprint Retrospective

Sprint No.	**Start/ End date**	**Sprint Goal**	**Status**	**Problem(s)**	**Solution(s)**
1	17/2/25 – 3/3/25	• All major mechanics implemented in singleplayer. • Code defensively	Achieved	• Effective development time per day lasts ~ 2 hours • Lack of concentration • Logging of small features not done	• Track status of small features. • Think before implementing. • Use logging and asserts.
2	4/3/25 – 16/3/25	• Multiplayer and UI	Achieved (with setbacks)	• Why doesn't this work. • Why are there 2 particle systems	• Do not watch youtube videos. • Read the documentation instead. • Improve.
3	17/3/25 – 31/3/25	• Initial Terrain implementation. • Initial game asset implementation. • Finish Multiplayer features.	Achieved	• Terrain is too large, needs downsizing. • Fireworks need improvements	• Just fix it.
4	1/4/25 – 15/4/25	• Implement more game assets (textures, meshes, etc.)	Achieved	• First half had no progress (Hari Raya celebration) • Move into hostel on the second week.	• Compensate for time loss. • Slowly but surely (written in Japanese).
5	16/4/25 –	• Story Mode (everything).	Achieved	• The modularity of GameController severely	• State Machines should be Loosely Coupled instead of

Sprint No.	Start/ End date	Sprint Goal	Status	Problem(s)	Solution(s)
	30/4/25	• Audio and Subtitles. • Initial Mission implementation.		limited the development time. • Question Data structure needed to be changed	Tightly Coupled. • Obtain clairvoyance.
6	1/5/25 – 15/5/25	• Splitter Gun implementation. • More game assets. • Full mission implementation.	Achieved	• Development slowed down due to assignments	• None.
7	16/5/25 – 30/5/25	• Final game asset implementation. • Terrain improvements. • Tutorial Implementation. • A lot of bug fixing.	Achieved	• Game code are reused in a bad way. • Conduct regression testing.	• Obtain clairvoyance.
8	31/5/25 – 7/5/25	• A lot of bug testing. • A lot of regression testing. • Finalize every feature as per its requirements.	Achieved (somewhat)	• Screaming "done" after a successful test does not make it a fully bug-free. • Build times severely impacted iteration time.	• Test more deeply. • Do not build after each and every minor bug fix. • Find a way to automate build process

5.4 Definition of "Done" and Game Testing and Evaluation

While it has room for improvement, the game is considered "Done" by the author on the 8th and final sprint of the project, the deadline of the project. The game can now be tested on the students for evaluation. As part of the project's objectives, Form 4 students were chosen for the game testing session. Two classes were chosen for this study, and each class was tested separately on different days. In total, testing took only two days using four periods of the timetable, meaning one hour for each class.

The students from each class were divided into control and experimental groups. The experimental group was further divided into teams of three to form collaborative learning teams to play the game. In each team, one member hosted a LAN game using a shared secret code, while the other two members joined as clients. The control group participants were individually given reading material as learning media, attached in Appendix I. The goal given to the experimental group was to advance in the Story Mode as far as they could within the allotted time frame (10 minutes before the period ends).

The game was installed on the school's laptops several days in advance to test compatibility, performance, and LAN connectivity. This process also required adjusting the laptops' application-specific firewall settings. The playtest was conducted during the class's Chemistry period and was limited to one hour to fit the timetable. Students were given 10 minutes to complete the pre-test and post-test, with 30 minutes allocated for the experimental or control session. Before starting the test, the teacher was given a consent form (attached in Appendix J) to allow testing of the students, and a short briefing was given to the students about the project. Then, the students were divided into experimental and control groups, who were then given pre-test questions.

For the pre-test, the experimental and control groups were given identical sets of questions, consisting of 10 balancing equation questions. The questions were given to check the students' understanding of the concept of balancing equations.

For the post-test, both experimental and control groups were given identical sets of questions, consisting of 10 balancing equation questions which were different from the pre-test questions. The post-test aimed to gauge how well the students understood the concept of balancing equations after playing the game or studying the learning material, which would then be compared against the control group to analyze the game's effectiveness. Both pre-test and post-test questions, attached in Appendix K, ensure a fair comparison for both groups.

The reading material, pre-test, and post-test questions were created with help from a content expert, who is an experienced Chemistry teacher. The difficulty of the pre-test and post-test questions was also verified as suitable for the Form 4 students by the content expert.

5.4.1 Participant Information

47 students from 2 classes, namely 4 Amethyst and 4 Emerald from Kolej Datu Patinggi Abang Haji Abdillah were chosen to be the participants for playtesting of Objective Terminal. It should be noted that, in contrast to the Emerald class, students of the Amethyst class take Computer Science as their STEM elective in place of the Biology subject. Students of each class was divided into experimental and control groups. Data from one class, or nine participants in the experimental group were included in the analysis, due to miscommunication during the briefing and a visual bug in the tutorial (see Chapter 6.3 Constraints and Limitations). In both control and experimental groups, some participant data had to be excluded as some individuals did not hand in either the pre-test or post-test paper.

Figures 5.1 and 5.2 show the gender distribution of participants included in the analysis for the experimental and control groups, respectively. In the experimental group, 9 out of 24 participants were included in the analysis – 7 males and 2 females. In the control group, 21 out of 23 participants were included, comprising 8 males and 13 females.

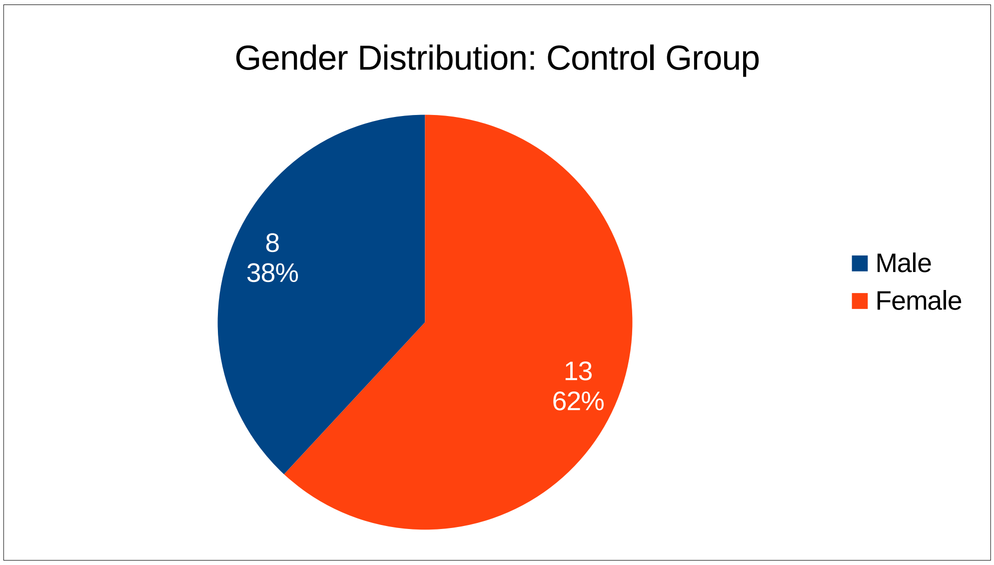

Figure 5.1: Control Group Gender Distribution

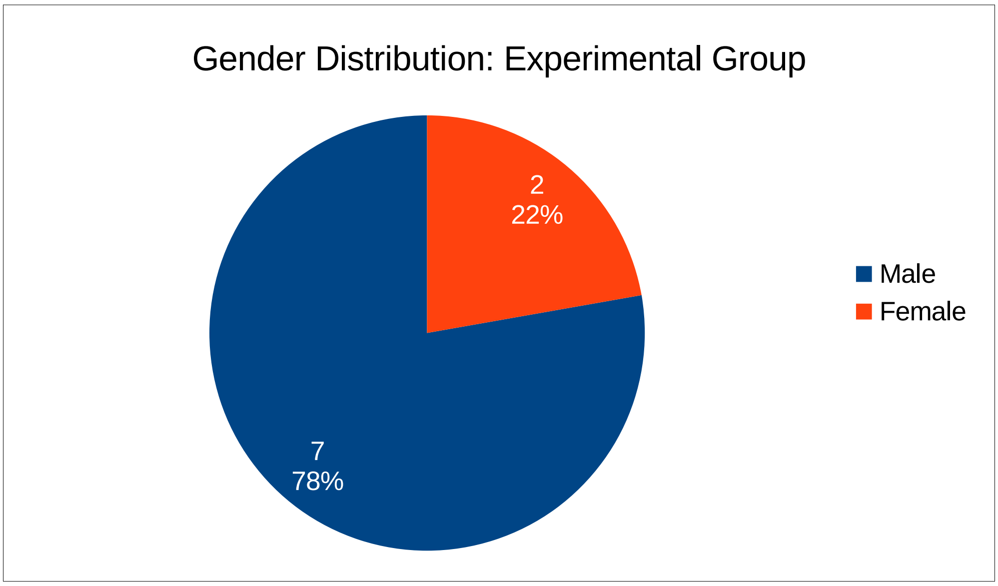

Figure 5.2: Experimental Group Gender Distribution

5.4.2 Pre-test and Post-test results

Table 5.3: Control Group results

Student	Pre-Test Marks	Post-Test Marks	Difference, x_d
1	1	0	-1
2	2	3	1
3	1	1	0
4	8	6	-2
5	1	3	2
6	9	8	-1
7	3	5	2
8	5	8	3
9	3	4	1
10	6	5	-1
11	2	3	1
12	1	1	0
13	2	3	1
14	7	8	1
15	6	7	1
16	5	5	0
17	1	1	0
18	2	3	1

Table 5.4: Experimental Group results

Student	Pre-Test Marks	Post-Test Marks	Difference, x_d
1	7	9	2
2	5	10	5
3	0	5	5
4	7	9	2
5	7	9	2
6	5	4	-1
7	7	5	-2
8	6	8	2
9	0	6	6

Table 5.3 and Table 5.4 above shows the marks for each student in the pre-test and post-test for the control and experimental group respectively. Table 6 presents data exclusively from those participants who successfully played the multiplayer Story Mode

together as a group. The control group used data from both classes, but had three participants whose data had to be excluded due to them achieving the highest possible marks in both pre-test and post-test. The paired samples t-test assesses whether it has a significant mean difference between two scores (pre-test and post-test scores), therefore including the full-mark participants in the analysis will not contribute any change in the calculated values.

A hypothesis testing using paired samples t-test was used to evaluate the scores for the control and experimental group separately. The paired samples t-test compares the scores of two groups to ascertain which has a higher impact.

Control group:

- Null Hypothesis, H_{0_C} : There is no difference in scores within the control group between the pre-test and post-test. (H_{0_C} :$\mu control$ = 0)
- Alternative hypothesis, H_{α_C} : There is a significant difference in scores within the control group between the pre-test and post-test. (H_{0_C} :$\mu control \neq 0$)

Experimental Group

- Null Hypothesis, H_{0_E} : There is no difference in scores within the experimental group between the pre-test and post-test. (H_{0_C} :$\mu experimental$ = 0)
- Alternative hypothesis, H_{α_E} : There is a significant difference in scores within the experimental group between the pre-test and post-test. (H_{0_C} :$\mu experimental \neq 0$)

Table 5.5 and Table 5.6 shows the comparison of the mean and standard deviation between the pre-test and post-test results for the experimental group and the control group respectively. The results were generated using Statistics Kingdom's Paired T Test Calculator

(Dependent T test). The experimental group's mean score increased from 4.9 in the pre-test and 7.2 in the post-test, whereas the control group's mean score increased from 3.6 in the pre-test and 4.1 in the post-test. A greater increase in the mean score was observed in the experimental group than the control group.

Table 5.5: Comparison of mean and standard deviation of Experimental group

	Experimental Group	
	Pre-test	Post-Test
Mean	4.9	7.2
N	9	9
Std. Deviation	2.9	2.2

Table 5.6: Comparison of mean and standard deviation of Control group

	Control Group	
	Pre-test	**Post-Test**
Mean	3.6	4.1
N	18	18
Std. Deviation	2.7	2.6

Table 5.7: Result of paired samples t-test for the experimental and control group

Paired Samples Test								
	Paired Differences							
Pair	**Mean**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Two-sided p**
				Lower	**Upper**			
Control_Pre – Control_Post	0.5	1.25	0.29	-0.12	1.12	1.699	17	0.1075
Experimental_Pre–Experimental_Post	2.3333	2.69	0.9	0.26	4.4	2.5997	8	0.03163

Table 5.7 shows the calculated result of the paired samples t-test on the pre-test and post-test results for both the experimental and control groups. A 95% confidence interval was used for the paired samples t-test, with $\alpha = 0.05$. For the control group, the calculated t-value is 1.699 with a p-value of 0.1075. The result is insignificant at $p < 0.05$. Therefore, we fail to reject the null hypothesis for the control group. For the experimental group, the calculated t-value is 2.5997 with a p-value of 0.03163. The result is significant at $p < 0.05$. Therefore, we reject the null hypothesis for the experimental group. The experimental group showcased a large difference between the pre-test, post-test results and mean score compared to the control group. This result indicates that the collaborative digital game has a significant impact on the students' understanding of The Mole Concept, Chemical Formula, and Equation.

5.5 Observations during Collaborative Learning

At the time of testing, Objective Terminal had a tutorial level out of the box. It was sufficient to explain the various features of the game. But when time came for them to play the Story Mode, the players were lost. At the start of a Story Mode, the buttons on the Molecule Dispenser were disabled whereas the Tutorial had all of the buttons be interactable. This resulted in the players getting stuck for a while, until they were given some guidance on how the game mode worked.

Additionally, despite the availability of a tutorial, students showed a reluctance to engage with it. This may be attributed to an unintended visual bug that caused the tutorial videos to display as black during their initial appearance, leading students to skip the tutorial without viewing its content. The story subtitles were similarly affected; several students did not realize that subtitles were present. Furthermore, the subtitles were rendered with 10% transparency due to limitations within Unity's TextMeshPro system, which likely contributed to the students overlooking them.

Once proper instructions were given (like reading the story subtitles), the students played the collaborative digital game as designed. The players assumed their roles by picking up tool guns, throwing molecule balls and exploring the level. Interestingly, one team formed a human chain by throwing Molecule Balls and picking them up for more efficient transportation to the tent. When the missions with balance equation puzzles came, the students had discussions, pulled out notes to write, and generally more engaged with the subject compared to the control group.

Chapter 6: Conclusion and Future Works

6.1 Introduction

This chapter addresses the accomplishment of the project objectives and explores the constraints and limitations encountered during the project. Additionally, suggestions to improve the learnability of the game and future works are presented.

6.2 Achievement of Project Objectives

Table 6.1 lists the project's objectives and its respective achievements.

Table 6.1: Project Objectives and Achievement

Objectives	**Achievement**
1. To design an engaging learning game focusing on the Form 4 KSSM Chemistry subject.	A game has been designed using the SCRUM methodology.
2. To develop a 3D multiplayer game that promotes collaborative learning by answering puzzles related to the Chemistry subject.	A 3D multiplayer game has been developed in the puzzle game genre. The game is focused on the topic of The Mole Concept and Chemical Equations, specifically on the concept of balancing chemical equations, with features designed around the concept of collaborative learning.
3. To evaluate the effectiveness of the game in regards to helping Form 4 students to study	The developed game's effectiveness was evaluated using pre-tests and post-tests

the Chemistry subject.	results from both experimental and control groups, utilizing paired samples t-test as the analysis method. The assessment showed that the experimental group showed significant improvement over the control group. Therefore, it was concluded that the developed game was effective in teaching the students.

6.3 Discussion

The results of the paired samples t-test reveal that students who participated in the collaborative digital game showed significantly greater improvement in their understanding compared to the control group that studied reading material. This suggests that the interactive and collaborative features of the game effectively enhance students' grasp of key chemistry concepts. The immersive environment and hands-on activities likely contributed to higher engagement and deeper learning, leading to measurable gains in academic performance. Overall, these findings indicate that integrating 3D collaborative games into chemistry education can be a powerful strategy for improving student outcomes.

While the findings are promising, the positive effects observed may be partially attributable to the existing chemistry among students, rather than the game or collaborative approach alone. Future studies should replicate the experiment with randomly assigned groups to better isolate the impact of the intervention. Additionally, comparing the game-based method with other collaborative activities could clarify whether the observed benefits stem from the game, its collaborative nature, or a combination of both.

It is notable that even though the students did not complete the story mode, participants in the experimental group showed significant improvement in their scores. This suggests that the game's design, particularly its visualization of abstract scientific concepts, may play a key role in facilitating rapid learning. Future research could examine whether longer exposure leads to even greater gains and further investigate which game elements are most beneficial for student learning.

6.4 Constraints and Limitations

There are several limitations to this study. First, all participants were from the same class and were familiar with one another, which may have positively influenced group dynamics and outcomes, potentially limiting generalizability to more heterogeneous or unfamiliar groups. Additionally, the comparison was made against traditional studying methods rather than other forms of collaborative learning, which limits the conclusions that can be drawn regarding the specific benefits of the game over other active learning strategies. Finally, the reading material for the control group did not include exercise materials, while the experimental group had access to extensive practice through the game. This disparity may have affected the performance of the control group.

Although two classes comprising 47 students participated in the playtest, data from only nine out of 24 students in the experimental group were included in the final analysis. This limitation was due to several factors: a miscommunication during the briefing, a typographical error in one of the puzzle questions (which incorrectly stated "Send an Oxygen atom" but only accepts "O_2 – molecular oxygen" as the correct answer), and the author's limited experience managing large student groups. These issues prevented several participants from completing the tutorial, resulting in their exclusion from the experimental group analysis. While a post-test was given to the affected students, their results were omitted from the study, as they did not have the opportunity to participate in the collaborative multiplayer mode. As a result, although the experimental group showed positive outcomes, the sample size for this group was relatively limited.

Additionally, the author was allotted only one hour to conduct the entire playtest session, which had to accommodate both the pre-test and post-test assessments. None of the students in the experimental group had time to complete the full story mode of the game, which typically requires about 35 minutes to finish. After accounting for delays and time for doing pre-test and post-tests, the play sessions during the study lasted only 20 to 25 minutes depending on the class. Therefore, it is possible that additional time with the game could result in further improvement in outcomes.

The computer lab had a shortage of mouse peripherals. This resulted in some participants – specifically three in both playtest sessions– using the laptop's touchpad to move the mouse pointer. This might have caused some frustration due to not being able to control the player as freely compared to using a mouse.

The game exclusively focuses on a single aspect within the broader topic of The Mole Concept and Chemical Equations—balancing chemical equations. While the Objective Terminal delves deeply into teaching the fundamentals and intricacies of balancing equations, it neglects the latter half of the topic: The Mole Concept itself. As a result, a significant portion of the curriculum remains unexplored, leaving learners with an incomplete understanding of the overall subject.

6.5 Future Works and Recommendation

There are number of recommendations to enhance the player's experience and to ensure that the learning objectives are met in future project. The list below outlines them:

- Randomize Group assignment
- Give clear instructions on the playtesting process
- Allocate more time for playtesting process.
- Test the game using randomly grouped students.
- Test the game against conventional collaborative learning teams.
- Prepare sufficient peripherals before playtesting.
- Voiceovers for story mode and tutorial.
- Mini-tutorial to explain mechanics of story mode.
- Add name functionality for LAN multiplayer games, 3D model for the player character and customizable accessories for greater player immersion.
- Add an "equation scale" which visualizes the balance equation puzzles in a numerical fashion, to better help players understand the concept more.
- Include features from cooking game genre, like multiple puzzles can be active at a single time for Blitz Balance Panic.

6.6 Summary

This chapter has discusssed the achievement of the project's objectives, discussion, constraints and limitations that were found throughout the project development and recommendations for improvements that can be made for future works.

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APPENDICES

Appendix A

Gantt chart for FYP 1 Schedule

Task Name	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Submission of Brief Proposal														
Submission of Full Proposal														
Submission of Chapter 1														
Submission of Chapter 2														
Submission of Chapter 3														
Submission of FYP 1 Final Report & Paper For Assessment														

Appendix B

Gantt chart for FYP 2 Schedule

Task Name	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Submission of Proposed/Revised Structure of FYP Report, Title, and Gantt Chart														
Design, and Implementation and Integration of Game Mechanics and Related Elements														
Submission of First Draft of Chapter 4														
Playtesting and Evaluation														
Submission of First Draft for Chapter 5, 6 and Abstract for Paper														
Submission of First Draft of FYP 2 Full Report and Paper														
Submission of FYP 2 Final Report, Source Code, Installation Kits, User Manual and Paper for Assessment														
FYP Symposium														

Appendix C

Interview consent form and interview questions

UNIVERSITI MALAYSIA SARAWAK

Faculty of Computer Science and Information Technology

Consent Form for Participation in Research Interview

Student: Imran Harriz bin Madzalan

Student Matric Number: 78048

Research Title: 3D Multiplayer Collaborative Learning Game – Objective Terminal.

The purpose of this study is to gather insights from experienced chemistry teachers about their use of game-based learning strategies in teaching chemistry concepts to students. The information collected will contribute to a the development of an educational chemistry game.

I confirm that my participation in this research interview is voluntary and that I have the right to decline answering any questions or stop the interview at any time. I also understand that this

interview will be recorded and transcribed for the research.

By signing this consent form, I confirm that I have read and understood the explanation given to me and agree to the terms above.

Signature:

Name: ______________________________

Date: ______________________________

Questions:

1. Can you describe how long have you taught Chemistry?
2. What specific Chemistry topic do Form 4 students often struggle with?
    1. Why do you believe students find it difficult to understand these topics?
3. What are your thoughts on using collaborative learning for teaching Chemistry?
    1. How often have you used this learning technique in class?
    2. Do you believe it helps them understand chemistry concepts?
    3. Do you believe it helps them memorise concepts better?
4. Do you have any experience in using collaborative learning applications online?
    1. What do you believe these applications lack the most?
5. How much experience in using educational games and Game Based Learning?
6. How well do you think conducting collaborative learning through an immersive game would improve students performance?
    1. Do you believe it can help students understand the topics they struggle with.
    2. Do you believe it will improve the student's motivation to learn chemistry?
7. What do think are the elements a GBL collaborative game need the most to effectively teach them chemistry?

Appendix D

Consent form and Questionnaire carried out on students.

UNIVERSITI MALAYSIA SARAWAK
Faculty of Computer Science and Information Technology
Consent Form for Participation in Research Survey

Student: Imran Harriz bin Madzalan

Student Matric Number: 78048 (Software Engineering course)

Research Title: Objective Terminal—3D Multiplayer Collaborative Learning Game.

The main purpose of this study is to gather insights from Form 4 Chemistry students regarding their opinion of topics in the Chemistry syllabus of Form 4. Next, gain perspective on student's interest in conducting collaborative learning activities via a digital game. The information collected will contribute to the development of an educational chemistry game.

Participation in this research interview is voluntary. Parents/guardians have the right to decline their child from answering this survey. Imran will see the data and Dr Amelia Jati, his Supervisor overseeing him to analyse the data. Imran will compile the data from all participants into a large spreadsheet that will be used for further study. However, once it has been compiled, it will be completely anonimized and you will not be identified with your data. The experiment may be published in an academic journal but the data will only be presented in summary form and you will not be identifiable in any way.

By signing this consent form, I, ____, as the parent/ guardian of ____, from class ___________, have confirmed that I have read and understood the purpose of the survey. I also agree to the terms outlined above.

Parent/ Guardian's Signature:

Date:

Section A: Demographic profile and Chemistry background

1. What is your Gender (circle one option)
   a) Male
   b) Female

2. In your opinion, which topic in the KSSM Form 4 Chemistry subject do you find the hardest? (circle up to three answers)
   a) Introduction
   b) Matter and the Atomic Structure
   c) The Mole Concept, Chemical Formula and Equation
   d) Periodic Table of Elements
   e) Chemical Bond
   f) Acid, Base and Salts
   g) Rate of Reaction
   h) Manufactured Substances in Chemistry

3. Why do you find these topics hard to learn? (circle up to three answers)
   a) The concepts are too abstract and hard to visualize.
   b) The topics require extensive memorization of facts and formulas.
   c) The material is presented in a confusing or unclear manner.
   d) I struggle with connecting the theoretical concepts to real-world applications
   e) I feel overwhelmed by the amount of information covered in each lesson or unit.
   f) I find it hard to stay motivated and interested in chemistry topics
   g) others (please state):
   ____

Section B: Opinions on digital games.

1. Which device do you regularly use to play video games? (circle all that apply)
   a) Personal Computer (PC) or Laptop
   b) Mobile Phone
   c) Tablet
   d) Video Game Console

2. Please state how much do you agree with the statements regarding video games.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I regularly play games.	○	○	○	○	○
I regularly play educational games.	○	○	○	○	○
I enjoy playing video games.	○	○	○	○	○
Playing video games has helped to improve my knowledge.	○	○	○	○	○
Playing educational games have increased my motivation to learn.	○	○	○	○	○

3. How interested would you be to play an educational game about the topics of Chemistry?

Very Uninterested ○ ○ ○ ○ ○ Very Interested

4. How interested would you be to play an educational game about the Chemistry topics that you struggle in?

   Very Uninterested ◯ ◯ ◯ ◯ ◯ Very Interested

5. How interested would you be to play a multiplayer game about the topics of Chemistry?

   Very Uninterested ◯ ◯ ◯ ◯ ◯ Very Interested

Appendix E: Mission List

Mission no.	Mission Type	Mission Description	Mission Object (How to get)	Answer	Rewards
1	Search	Search for objects that contain Oxygen and Nitrogen	Air (Use Duplicator Gun while aiming at the sky)	Drop Nitrogen and Oxygen Molecule balls into Answer Chute	Dispenser is now able to dispense Oxygen and Nitrogen Achievement: Reach for the skies! (first mission complete)
2	Balance	Balance $N_2 + O_2 = 2NO_2$	-	Drop these three Molecule Balls into Answer Chute: $N_2 + 2O_2 = 2NO_2$	Score + 1000
3	Search	Search for objects that have Carbon	Wood (Use Duplicator Gun at the tree next to the Tent)	Drop Carbon Molecule Ball into Answer Chute	Dispenser is now able to dispense Carbon
4	Balance	Balance $C + O_2 = 4CO_2$ combustion reaction	-	Drop these three Molecule Balls into Answer Chute: $4C + 4O_2 = 4CO_2$	Score +1000 Announcer Tent is available to explore Achievement: Apprentice Chemist (Announcer Tent reached)
5	Search	Search for objects that have Iron and Copper	Tent peg for Iron (from any tent), Exposed	Drop Iron and Copper Molecule Balls into Answer Chute	Dispenser is now able to dispense Iron and Copper

			Wiring at Announcer Tent.		
6	Search	Search for objects that contain Sulphur	Normal, unexposed wires (anywhere)	Drop Sulphur molecule ball into Answer Chute	Dispenser is now able to dispense Sulphur
7	Balance	Balance: $4Fe + O_2 = 2Fe_2O_3$ combination reaction	Iron for Tent	Drop these three Molecule Balls into Answer Chute: $4Fe + 6O_2 = 2Fe_2O_3$	Score + 3000
8	Balance	Balance: $Cu + 2S = Cu_2S$ “copper sulfide is a common ore by mining industries	Iron for Wires, Sulphur for rubber coating	Drop these three Molecule Balls into Answer Chute: $4Cu + 2S = 2Cu_2S$	Score + 1000 River is available to explore Achievement: We intended go to sea (river reached)
9	Search	Search for objects that contain Hydrogen	Riverbed (Use duplicator gun while aiming at riverbed)	Drop Hydrogen molecule ball into Answer Chute	Dispenser is now able to dispense Hydrogen
10	Search	Search for objects that have Silicon	Sandy area near the river	Drop Silicon molecule ball into Answer Chute	Dispenser is now able to dispense Silicon
11	Balance	Balance: $SiO_2+C=Si+CO$ “silicon has many uses; jewellery, computers and solar panels, even the glass you’re looking at	(chip and quartz for firework controller cpu)	Drop these four Molecule Balls into Answer Chute: $SiO_2+2C=Si+2CO$	Score +1000 Bazaar is now available to explore Achievement: Chip manufacturer

		right now"			
12	Search	Search for objects containing Sodium and Chlorine	Salt bag from one of the Bazaar stalls	Drop Sodium and Chlorine molecule balls into Answer Chute	Dispenser is now able to dispense Sodium and Chlorine
13	Balance	Balance: H_2SO_4+NaOH = Na_2SO_4+H_2O (neutralization)	(cleaning agent for firework launcher)	Drop these four Molecule Balls into Answer Chute: H_2SO_4+2NaOH = Na_2SO_4+2H_2O	Score + 3000
14	Search	Search for objects that have Aluminium	Aluminium foil from one of the bazaar stalls	Drop Aluminium molecule ball into Answer Chute	Dispenser is now able to dispense Aluminium
15	Balance	Al+3$CuSO_4$=$Al_2(SO_4)_3$+Cu (single displacement)	Water purification	2Al+3$CuSO_4$–>$Al_2(SO_4)_3$+3Cu	Score + 3000 Achievement: Water Purifier
16	Balance	C_2H_4 + O_2 = H_2O CO_2 (alkane combustion reaction)	Part of chip authentication	C_2H_4 + O_2 = H_2O CO_2	Score + 5000
17	Balance	Balance: $CuSO_4$+NaOH–>Cu(OH)2+Na_2SO_4 (double displacement)	Part of chip authentication	$CuSO_4$+2NaOH–>Cu(OH)2+Na_2SO_4	Score + 5000 Achievement: Heroes (finished story mode)
18	Balance	Send 10H_2O	Part of cleaning up	10H_2O	Score + 10000 Achievement: Helpful Chemist

Appendix F: "Objective Terminal Narrative" Document

(constraints: have to reuse the current working tent, announcer tent, bazaar and riverside area, and the whole firework festival thingy, mainly to prevent building the whole scene from scratch. That means no fantasy, high concept and stories that may require a stylized scene to fit the story.)

AI used: sonar-pro from labs.perplexity.ai. The generated output chosen was after more than a dozen output re-generations.

prompt:

> You are a creative writer tasked with generating an engaging narrative for a collaborative chemistry-focused game. Use the following constraints and elements, keeping the story imaginative and intriguing:
>
> Setting: The narrative must utilize the following locations without creating new ones: a working tent, an announcer tent, a bazaar, and a riverside area. The story is tied to a summer firework festival.
>
> Timeframe: The story begins on the day before the festival.
>
> Core Mechanics: Highlight the use of "Chemistry is all around us" as a theme and show how the characters work together to duplicate, split, and combine natural elements in creative ways to prepare necessary items, such as cleaning solutions, cooling agents, heating elements, metals, and computer parts. There is also a machine called the molecule dispenser which takes inspiration of a vending machine that is able to dispense molecules.
>
> Tone and Purpose: The story should be lighthearted but with a touch of urgency. The goal is to entertain while promoting themes of collaboration, creativity, and resourcefulness.
>
> Output Format: Provide a narrative in prose form, suitable for a game script or story outline, and ensure it includes character dialogue, descriptions of the setting, and clear progression of the plot.

Synopsis:

The day before the much-anticipated Firework Festival—a celebration marking the height of summer with dazzling lights and delicious food—chaos looms on the horizon. The school-led committee tasked with organizing the fireworks realizes they lack the essential materials to launch the show. In desperation, the Committee President brings together their close friends to execute a last-minute, high-stakes plan: crafting the necessary materials to ensure the firework launcher functions perfectly before the festival grounds open. This means assembling critical items, such as cleaning supplies, cooling agents, heating components, metals for the launcher, computer parts, and more. (Note: the gameplay is not focused on making fireworks themselves).

Using the mantra "Chemistry is all around us," players must combine, split, and duplicate elements sourced from the environment. The goal? Complete the preparations without being discovered. Will they rise to the occasion and save the festival in time, or will it all end in disappointment?

Detailed Story:

Upon starting the level, players are directed to the Working Tent, where they receive their first instructions from the Committee President. Here, the current predicament is laid out: players must prepare the essential materials for the firework launcher, ensuring seamless operation. To contribute, they must drop the required molecules into the Answer Chute that sends them across the river to the Firework Committee for processing.

In normal circumstances, the Working Tent houses a Molecule Dispenser capable of producing the needed molecules. However, due to unforeseen issues, the dispenser is out of stock. Anticipating this setback, the Committee President enlists the players' help to locate and harvest essential molecules from everyday items, referred to as "Mission Objects." These objects include commonplace materials such as wood, water, wires, and cooking salt.

Innovative Tools for Molecule Management

Players are equipped with two specialized tools:

1. **Duplicator Gun**: Duplicates Mission Objects to generate molecule balls.
2. **Splitter Gun**: Breaks down these molecule balls into their constituent atoms.

The goal is to strategically duplicate Mission Objects and extract the necessary components while avoiding unnecessary disruption. If Mission Objects are removed or compromised, the team's score will be penalized.

Mission Progression and Exploration

Gameplay involves a treasure hunt to locate Mission Objects scattered across the map's various zones, including the Working Tent, Bazaar, and River. However, Mission Objects only spawn once their corresponding mission has been assigned. This progressive structure—paired with an expanding exploration area—creates a sense of accomplishment and escalating difficulty. Players initially begin confined to the Working Tent and gradually unlock access to new areas, such as the riverbank and the bazaar, as they advance through the missions.

Each area presents unique challenges and opportunities, ensuring the experience stays engaging and dynamic. Will the players successfully gather everything before the festival begins, or will they be discovered and risk the festival's failure? The clock is ticking, and the stakes are high!

--- end of AI output.

Game design note: Missions alternate between Search missions and Balance missions. Search missions require players to restock the dispenser by finding Mission Objects. Balance Missions require players to answer the question given. In both mission types, the molecules gained from the Mission Objects or the balanced molecules are to be dropped into the Answer Chute to complete the mission. The story progresses with each mission completed. There is a list of missions for the players to complete later in the document, with the stories attached to it.

More prompts:

> Generate a detailed outline for a science-themed adventure game where players must work together to save a firework festival by solving chemistry-based puzzles. Include the following elements:
>
> Characters: Create a main guiding character (e.g., the Committee President), explain their role, and describe the players' role in the story.
>
> Stakes: Describe the stakes of the game, including what happens if the players fail or succeed.
>
> Mission Structure: Divide the story into multiple missions, each with clear objectives and challenges. Include progression mechanics, such as unlocking new areas and increasingly complex tasks.
>
> Gameplay Mechanics: Incorporate chemistry-based gameplay elements like balancing equations, combining elements, and gathering resources with tools like a Duplicator Gun, Combiner Gun, and Splitter Gun. Include examples of how these tools are used.
>
> Challenges and Plot Progression: Add twists, such as unexpected difficulties, time constraints, and high-stakes moments to drive tension.
>
> Finale: Describe how the game ends, including a climactic moment where the players solve a major challenge or puzzle. Mention any post-completion tasks, such as cleanup or scoring.

AI Output (after what felt like 500 years of re-submitting the same prompt):

Output was altered a lot, mainly because of the AI hallucinating.
Characters:

- **Committee President**: The leader of the Firework Committee. A resourceful and high-spirited individual who guides the players through the entire operation. They are meticulous, ensuring every detail is accounted for, and they explain the reasoning behind each task.

- **The Players**: A group of friends called in to help save the firework festival. Equipped with tools like the Duplicator Gun, Splitter Gun, and Combiner Gun, they play a critical role in sourcing, combining, and crafting the materials needed to complete the firework launcher.
- **Firework Controller**: The final stage of the operation brought to life. It provides chemical puzzles to unlock its functionality, becoming both the players' last hurdle and the symbol of their success.

Stakes:

- **Save the Firework Festival**: The festival is at risk of failure unless the firework launcher can be completed in time. Players must work against the clock to gather materials, solve chemical equations, and construct the required systems.
- **Stealth is Key**: Players need to operate covertly, ensuring no unnecessary disruptions or missing Mission Objects, as penalties can lower their final score.
- **Dynamic Challenges with a Time Limit**: The discovery of missing materials and the looming threat of failure intensify the urgency of the operation.

Mission Objectives:

Mission 1: Setting Up the Basics

- Briefing: Players are tasked with checking the functionality of the Answer Chute and Molecule Dispenser.
- Objective: Use nitrogen and oxygen (commonly found in the air) to test the system.
- Success: The equipment is operational, laying the groundwork for future tasks.

Mission 2: Testing the Tools

- Players are instructed to balance a simple equation using the Question Terminal to confirm the Duplicator and Combiner Guns are working.
- Objective: Balance the given equation and ensure tools are ready.
- Success: The tools are validated, and materials like fuel, oxygen, and a fire extinguisher are prepared for the team for later use.

Mission 3: Gathering Key Resources

- Materials Needed: Iron for tent poles and Copper for wires.
- Players are tasked with exploring the area to find these resources.
- New Challenge: The President realizes rubber is needed to coat the wires for outdoor and high-temperature durability. Players must locate Sulfur to vulcanize the rubber.

- Objective: Solve another equation to create rubber and construct the tent framework.
- Success: The groundwork is laid for the firework launcher system.

Mission 4: Unlocking the Bazaar (Advanced Materials)

- New Exploration Zone: The bazaar becomes accessible.
- Materials Needed: Sodium and Chlorine for salt.
- Objective: Search for kitchen materials in the bazaar and balance a provided equation for salt creation.
- Complication: A Sodium ball falls into the river, causing a time crunch.
- Success: Salt is prepared, and new materials are gathered.

Mission 5: High Stakes Chemistry

- Materials Needed: Copper (already found) and Aluminum for the firework launcher's control unit.
- New Challenge: Players must solve a difficult chemical equation involving a redox reaction.
- Objective: Explore further to find Aluminum, solve the complex equation, and help construct the launcher's CPU.
- Success: The control unit is one step closer to completion.

Mission 6: Cleaning Operations

- Problem: The Answer Chute is making strange noises due to accumulated dirt.
- Materials Needed: Heavy-duty cleaning agents (Sulfuric Acid), requiring Hydrogen.
- Objective: Find Hydrogen near the riverside, solve an equation for a strong acid-base reaction, and clean the chute.
- Success: The chute is restored, ensuring smooth processing of materials.

Mission 7: Final Puzzle – The Firework Controller

- Final Materials: Silicon and Quartz are needed to complete the CPU oscillator, which is critical for the firework launcher's operation.
- Objective: Players locate Silicon and solve an equation to finalize the controller.
- New Challenge: The Firework Controller is locked and requires players to solve a series of chemical puzzles to unlock.
- Stakes: The festival's success depends on solving these final puzzles.

Finale:

- **Final Equation Marathon**: The Firework Controller presents 3 equations that players must solve to unlock it. The President cheers the players on, adding tension and urgency to the moment.
- **Success**: The Firework Controller is activated, and the firework launcher is operational.
- **Cleanup Mission**: A chemist's job isn't done without proper cleanup. Players must deliver water to the Answer Chute to clean up after the operation.
- **Score Screen**: Players' final score is displayed, along with their number of mistakes and achievements, providing a sense of accomplishment or areas for improvement.

Conclusion:

The Firework Festival is saved thanks to the players' efforts. With dynamic missions, escalating challenges, and engaging chemical puzzles, the gameplay provides both educational value and entertainment. The fireworks fill the night sky, marking the end of the game and the players' success!

Appendix G: Story and Tutorial Dialogue.

Mission 1:

Hello~? Hello, oh, it looks like its working and it seems everyone is here too. The question terminal works OK which means we are good to go. We don't have much time, so I'll give you guys a quick briefing. In case you guys have forgotten, the fireworks festival starts tomorrow, and we are in charge with manning these two tents: The Working tent, which you guys are handling, and the Firework tent which you guys can see over the river. Well, if it was here. The personnel handling them were supposed to come yesterday, but as you can see, there is no tent. They did leave the Question Terminal and a table however. How kind of them. Which brings us to the problem.

We can't have a fireworks festival without the fireworks nor the safety equipment that comes with it.

Everyone, inside and outside of school is looking forward to this event. We cannot let them down.

This shouldn't have happened in the first place, I could've prevented this as the president,

But now is not the time for regrets. We have to build the parts ourselves, and I need you guys' help.

Luckily, the school was in charge with preparing the Working tent, which means we have everything we need to do this.

First, I need you guys to refill the Molecule Dispenser, not all of them, just the essentials.

it would be good if you guys can, but its not necessary.

So pick up a tool gun and go around, find an object that contains specific atoms and use it on them.

Go treasure hunting, basically.

If it works, then grab the molecule balls and put it into the Answer Chute. Oh, and try not to break anything.

We have permission from the teachers, but destruction of private property will be in our name.

WE have to pay for it if something breaks or goes missing.

So it's best if you guys can Duplicate the object first to copy whole thing,

And then split the duplicated object to get the atoms inside.

Got it? good. Let's start by finding Nitrogen and Oxygen, air.

The Duplicator Gun and Splitter Gun only works if the object being aimed at has a large percentage of atoms it in it.

Try aiming at the air, see it it works.

Mission 2:

Good job, we got the molecules too, so the Answer Chute is working properly.

The Answer Chute is also connected to the Dispenser. See the yellow Molecule Dispenser near the tent?

It should be able to dispense Nitrogen and Oxygen now that it has been restocked.

Alright. To build the parts needed, we need more than atoms so you guys have to do some Chemical Equation Balancing.

Lets warm up with a simple chemical equation. In case you guys have forgotten,

It is all about numbers. Count the number of atoms on both sides and then adjust the coefficient to match the other side.

Press the buttons on the Molecule Dispenser, then grab the molecule ball into the tent.

Duplicate the molecules first to match the number of atoms needed using the duplicator gun,

Then Combine the molecules together by making sure every molecule is in the scanner sphere.

So one person each for the duplicator and combiner guns, and one person handles molecule balls.

If you guys somehow forgot training, take a good look at the whiteboard. We scribbled some notes there.

Simple right? Now send us the balanced molecules.

Mission 3:

See, easy right? Once you start thinking of balancing numbers it starts to make sense.

My seniors taught me that technique, and its good knowledge to pass down.

Now, lets continue the treasure hunt. We need fuel and fire extinguisher material. We have a fire extinguisher,

But it seems to have run out. Don’t ask how we’re going to refill it. As for fuel, it actually gets chilly at night.

So its for us to warm up, despite the fireworks launching. Now what is a good candidate? Hmm…

Oh, wood, Carbon! Find carbon and put it into the Answer Chute.

Mission 4:

Good. The dispenser should be able to dispense Carbon now right? Try not to press it too much.

Now, to make the fuel and fire extinguisher Material. I've sent the equation for you guys to balance.

Carbon is the fuel, and carbon dioxide is the fire extinguisher material. Again, don't ask how we refill the extinguisher.

Sorry that we have to send these requests in the form of balancing equations. The system cannot give simple requests.

Who built this? Anyway, send us the balanced molecules.

Mission 5:

Thanks. Now we have a safety precaution in case something gets caught on fire.

You guys can now explore the Announcer tent area. It's going to be quite tricky finding these things.

We can now start building the tent but for that, we need Iron and Copper. Iron for the tent poles,

And copper for wiring.

I feel like I'm missing something, but for now get those atoms to refill the Molecule Dispenser.

Mission 6:

I think I found what I was forgetting. Good quality rubber. No wonder the wires kept combusting.

See, the fire extinguisher came in handy! N-no, refilling it is a family secret. Don't ask about it anymore.

To make durable rubber for wiring, it needs to be vulcanized. The name is fancy but it's just adding sulphur to it.

So, find some sulphur. Find wires around the announcer tent. It should drop Sulphur when splitting it.

Don't destroy the wires! Duplicate, then Split!

Mission 7:

I hope you guys didn't destroy the wires. If you guys did, it'll cost us a thousand *beep*, and we have to pay for it!

Time to move on. What were we up to again? Oh the tent. I've sent you guys an equation to balance.

Check the Question Terminal.

This one is the chemical equation for the formation of iron (iii) oxide, a type of combination reaction.

We just need the Iron and the iron oxide for the red color. No, its not rust, as it doesn't have water in its composition.

Give us the balanced molecules and we'll give you guys another.

Mission 8:

Nice, I've sent another chemical equation to balance. This time its for Sulphur and Copper.

We accidentally used the only copper molecule we had, so thanks in advance. *clears throat* As I said before,

The sulphur is needed for the vulcanization of rubber, the process that makes rubber more durable.

This is especially important in wires. Everything would be on fire if wires aren't vulcanized.

The Copper Sulfide on the other hand, is the molecular formula of copper ore. A valuable mining material called "Chalcocite"

Send them balanced molecules and we will have a tent! Its getting hot out here, so please hurry!

Mission 9:

We’re halfway to finishing the our job here. From here on, you guys can visit the riverbank!

Don’t get too carried away there! As we need some Hydrogen for the next set of reactions.

Go to the river and find hydrogen while we set up the tent here.

Mission 10:

Oh that was fast. We’re still setting the tent up. Amazing how 3 set of hands slow things down.

Since we’re still in a pickle here, go find something simple, but special. That’s right, Silicon!

Silicon has many uses, jewellery, computers and solar panels, even the glass you’re looking through right now.

And in our particular case a CPU and it’s oscillator. Both require Silicon to produce albeit in different varieties.

We are going to make the Firework Launcher’s Controller using the silicon varieties.

Drop the silicon in the Answer Chute once you guys have found it.

Mission 11:

Good work. The molecule ball left quite a mess in the Answer Chute but we’re going to handle that later.

I sent you guys an equation to balance, it’s rather simple, but very important in the field of semiconductors.

It’s the formula to produce pure silicon for production of CPUs. Conveniently, it has the formula for Quartz,

Which is used for the CPU’s oscillator, or its timer. Its also used in watches that run endlessly without batteries.

Also it’s used in – oh sorry, I went off there. Uh, give us the balanced molecules.

Mission 12:

Thanks. We’ll start building the Firework Launcher Controller, and you guys can go to the bazaar.

I doubt there is anything to eat, but don’t touch anything! The locals are using them, not the school.

The Answer Chute is making some weird sounds, so it might be dirty from all the molecule balls being thrown.

We need some salt as cleaning agent, and for that we need some sodium. Some of the locals might leave some salt there,

So go ahead and find some Sodium and put it into the Answer Chute. Once again, don't break anything!

Mission 13:

This will be quite the long chemical equation as it's a neutralization reaction. To put it simply,

Its a reaction where acids and alkalis come together to create salt and water. In this case, Sodium sulphate.

A wonderful cleaning agent for removing hard stains. The water in the equation washes away the dirt.

Be careful with the hydrochloric acid and sodium hydroxide, both can burn your skin!

Insert the balanced molecules to the answer chute while we figure out how to set up the firework launcher controller.

Mission 14:

Oh that was fast. I see you guys are getting the hang of it. It doesn't seem to make any weird sounds anymore…

Hey its cleaner too, good job! What? Give me a second…

It's not really for the tent, but someone's throat is dry. Clean water, to be exact. We already have the river, so…

Oh right, aluminium! You guys find aluminium, and put it into the Answer Chute. I need to confirm something.

I told you to bring more water!

Mission 15:

Nice. Check the terminal, I sent you guys a chemical equation to balance. If I am not mistaken,

this is a single displacement reaction.

This reaction is where the anions exchange cations, or aluminium taking the sulphate ion from the copper.

This is due to aluminium being more reactive than copper. More importantly, this reaction has aluminium sulphate.

Alumimnium sulphate is used by water treatment plants to purify water in a process called coagulation.

The molecule itself wont be ingested but as one part of the treatment process. In our case,

We treat the water using the molecule and distill the treated water using a makeshift solar still.

It wont be 100% clean but we don't want to look too suspicious buying water and returning here.

Anyway, give us the balanced molecules. Someone is… dehydrated so to say.

Mission 16:

Thank you for the water, I am alive! – You heard her. She handles receiving the molecules from you guys.

Anyway, it seems like our job is done! The Firework Launcher Controller is connected and we're good to go…?

The question terminal, it sent a request to you guys. No the controller did! It's part of the authentication process?

One wrong answer and fireworks will launch?! Who made this controller?! The launcher is not loaded so how did it…

If a firework launches, we'll be found out. That means getting nagged by mom… Now is not the time!

Only you guys can handle this problem. I trust you guys can finish this equation. Send us the balanced molecules!

Mission 17:

Its 2 factor authenticated huh… Oh, it sent another one. A double displacement equation? Very smart.

Its a type of reaction where both molecules exchange cations. Isnt this the one we do in labs?

Its the kind that either creates a soluble liquid or precipitate or water. You guys have gone this far, Don't give up yet! Send us these molecules! So that we can finish what we started!

Good luck.

Mission 18:

Thank you, all of you. You saved a life. More importantly, you guys saved the firework festival!

If the people giving the firework materials actually do come tomorrow, our efforts will not be in vein.

The people, the expectations and experiences we are in charge of have at least been protected.

Oh, one last thing before we go and regroup later. We need to clean the answer chute and the firework marks.

Send us water, a lot of them. Check the question terminal, this will be the last I promise.

Tutorial Mission 1:

Hello? Oh good, you're finally here! Wait, that's not a familiar voice.

Oh you're new here? No training? But we're starting right now… Ah whatever.

Listen to my instructions and learn the process on the fly. All good?

Quick, go to the Dispenser and get a Carbon atom!

Pick it up and throw it into the Answer Chute.

Tutorial Mission 2:

Nice, we got it. We need some oxygen here. The questions will pick up pace soon.

So go to the dispenser, get the atom and place it inside the tent. Pick up the yellow duplicator gun,

point at the molecule and shoot. Another molecule should come appear.

Don't play with it too much, or else we're going to run out of molecules!

Once you have two Oxygen molecule balls, pick up the white combiner gun.

Make sure the two oxygen molecule balls are inside the Scanner Sphere, and then shoot.

A bigger molecule ball should appear. Drop the gun and try inspecting it (Right mouse button)

Then, pick it up and throw it into the Answer Chute. The faster the better.

Tutorial Mission 3:

Nice! You're getting the hang of this. Check the Question Terminal, we have our first Balance Equation.

This equation doesn't exist naturally but it's a good learning experience. ($Al_2(SO_4)_3$)

When it comes to balancing equations, there is a trick to it: counting the number of atoms in the molecule.

On the left side, we have 1 Aluminium atom, 1 sulphur atom and 4 oxygen atoms.

On the right side, we have 2 aluminium, 3 sulphur and 12 oxygen atoms.

Why 3 sulphur and 12 oxygen you ask? Do you see the parentheses surrounding the SO_4?

Think of it as a multiplier, like in mathematics. In this case, the multiplier is 3

as seen by the small number after the parentheses.

1 x 3 is 3 so 3 sulphur, and 4 x 3 is 12 so 12 oxygen. Understand? Good.

Now we need to match the left and right side. The reason the question is called a balance equation

is because one side is not equal to the other.

In this question, 1 aluminum is not equal to the 2 aluminium on the right,

1 SO_4 on the left is not equal to the 3 SO_4 on the right, and so on.

So there should be 2 aluminium and 3 SO_4 on the left side!

Now, In order to finish these questions, you have to send the answers piece by piece,

meaning you need to send 3 or more molecule balls to complete the question.

Got it? Now send us the balanced equation so that we can launch these fireworks.

Appendix H: List of Achievements

No.	Type	Name	Description	Requirement
1	Story Achievement	Reach for the skies!	Find the first mission object	Complete Mission 1
2	Story Achievement	Apprentice Chemist	Unlock the Announcer Tent area	Complete Mission 4
3	Story Achievement	Everyday Chemist	Unlock the Bazaar Area	Complete Mission 8
4	Story Achievement	We intended to go to sea	Unlock the River area	Complete Mission 12
5	Story Achievement	Chip Manufacturer	Unlock silicon in the Molecule Dispenser	Complete Mission 16
6	Story Achievement	Heroes	Complete the story	Complete Mission 20
7	Story Achievement	Helpful Chemist	Clean up after finishing the story	Complete Mission 21
8	Secondary Achievement	Careful Chemist	No Mission objects were tampered or destroyed	No Mission Objectives Destroyed
9	Secondary Achievement	Flawless	No Wrong Molecules sent/ No mistakes	No Wrong Molecules sent/ No mistakes
10	Secondary Achievement	Fully Operational	Complete the Molecule Dispenser	Complete the Molecule Dispenser
11	Secondary Achievement	Energetic team	Complete All missions within 15 minutes	Complete All missions within 15 minutes
12	Secondary Achievement	Highly Energetic team	Complete All missions within 5 minutes	Complete All missions within 5 minutes
13	Secondary Achievement	Two Stage Firework	Complete all secondary achievement	Complete all secondary achievement

14	Secondary Achievement	Three Stage firework	Complete all secondary achievement	Complete all secondary achievement

Appendix I: Reading Material

Balancing Equations: A Guide.

Why Balance Equations?
Balancing equations is a key skill in chemistry, but the idea comes straight from math: what goes in must come out. In other words, the total number of atoms for each element must be the same on both sides of the equation. This is called the Law of Conservation of Mass. As students, whenever these questions are given, they're already answered! All the Molecules in the equation are correct, but not the coefficients. Which is where you come in.

Thinking of Equations as Numbers:
Imagine a chemical equation is just like a math equation. The equal sign tells you both sides must "add up" to the same amount. In chemistry, instead of numbers or variables, you're balancing atoms.

For example:

$$H_2+O_2 \rightarrow H_2O$$

Think of the arrow like an equals sign. Now, count how many H (hydrogen) and O (oxygen) atoms are on each side.

- Left: 2 hydrogen, 2 oxygen
- Right: 2 hydrogen, 1 oxygen

The numbers aren't balanced for oxygen, so we need to fix it by using *coefficients* (numbers in front), just like multiplying terms in math.

Steps to Balance Equations by Counting Atoms

1. List the Atoms

Write down how many of each atom you have on both sides:

- For $H_2 + O_2 \rightarrow H_2O$:
  - Left: H = 2, O = 2
  - Right: H = 2, O = 1

2. Change Coefficients to Balance
- Only change the big numbers in front (coefficients), not the small numbers below.
- For our example, there are two hydrogens on both sides. But only one oxygen on the right, so we need two.
- Put a 2 in front of H_2O:

$$2H_2 + O_2 \rightarrow H_2O:$$

Now, count again:
- Left: H = 2, O = 2

- Right: H = 4, O = 2

Now hydrogens don't match! There are 4 on the right but only 2 on the left.

3. Balance the Other Atoms

Put 2 in front of H_2:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Count:
- Left: H = 4, O = 2
- Right: H = 4, O = 2

Done!

Tips:
- Always balance one type of atom at a time; start with elements that appear only once on each side if possible
- If you get stuck, try balancing atoms that appear in only one molecule on each side first.
- Leave hydrogen and oxygen for last, since they're often in many compounds
- If you end up with fractions for coefficients, multiply everything by the denominator to get whole numbers

Example: Balancing a More Complex Equation

Unbalanced:

$$Fe+O_2 \rightarrow Fe_2O_3$$

1. List atoms:
- Left: Fe = 1, O = 2
- Right: Fe = 2, O = 3

2. Balance Fe:
- Put 2 in front of Fe:

$$2Fe+O_2 \rightarrow Fe_2O_3$$

- Now Fe is balanced.

3. Balance O:
- Left: O = 2, Right: O = 3.
- Find a common multiple (6). Put 3 in front of O_2 and 2 in front of $2Fe_2O_3$:

$$4Fe+3O_2 \rightarrow 2Fe_2O_3$$

- Left: Fe = 4, O = 6
- Right: Fe = 4, O = 6

Remember:

Balancing equations is like solving a puzzle. It's about making both "sides" of the equation "add up" to the same total. By treating it like a numbers game—counting and adjusting just the coefficients—balancing any equation becomes a logical process. Practice a few examples, and you'll get the hang of it!

Appendix J: Teacher Consent Form

UNIVERSITI MALAYSIA SARAWAK
Faculty of Computer Science and Information Technology
Consent form for Conducting Research on Students

Student: Imran Harriz bin Madzalan
Student Matric Number: 78048
Research Title: Objective Terminal – 3D Multiplayer Collaborative Learning Game.

The main purpose of this research is to gather insights on the effects of conducting collaborative learning sessions in an interactive 3D digital game to teach Form 4 students Chemistry. The study has 3 phases, listed below.

1. Pre-test phase
2. Experimental/Control phase
3. Post-test phase

The Experimental/Control phase has the participants involved split into two groups, the Experimental Group and the Control Group. Participants in the Control Group will study a given reading material whereas the Experimental group will play the 3D Collaborative Game. In both the Pre-Test and Post-Test phase, all participants are given a test containing 10 questions related to Balancing Equations to gauge the effectiveness of the game.

The responses will be kept completely confidential and anonymous. Any information the student provides is intended solely for research purposes and will not be shared with any external parties. Imran will see the data and Dr Amelia Jati, his Supervisor overseeing him to analyse the data. Imran will compile the data from all participants into a large spreadsheet that will be used for further study. Once it has been compiled, it will be completely anonimized and the responses will not be identifiable with the students.

By signing this consent form, I, ____, as the teacher of class ____________, have confirmed that I have read and understood the purpose of the survey. I also agree to the terms outlined above.
Teacher's Signature:
Date:

Appendix K: Pre-test and Post test Questions

Pre Test

Name: ________________________________

Class: ________________________________

Marks: ________________________________

Instructions: Every equation below is unbalanced. Write the balanced version in the blank spaces.

1. ___ Na + ___ $H_2O \rightarrow$ ___ $NaOH$ + ___ H_2
2. ___ C_3H_8 + ___ $O_2 \rightarrow$ ___ CO_2 + ___ H_2O
3. ___ $AgNO_3$ + ___ $NaCl \rightarrow$ ___ $AgCl$ + ___ $NaNO_3$
4. ___ N_2 + ___ $H_2 \rightarrow$ ___ NH_3
5. ___ Fe + ___ $O_2 \rightarrow$ ___ Fe_2O_3
6. ___ Al + ___ $Fe_2O_3 \rightarrow$ ___ Al_2O_3 + ___ Fe
7. ___ Cu + ___ $HNO_3 \rightarrow$ ___ $Cu(NO_3)_2$ + ___ NO + ___ H_2O
8. ___ C_7H_{16} + ___ $O_2 \rightarrow$ ___ CO_2 + ___ H_2O
9. ___ H_2SO_4 + ___ $HI \rightarrow$ ___ H_2S + ___ I_2 + ___ H_2O
10. ___ C_2H_6O + ___ $O_2 \rightarrow$ ___ CO_2 + ___ H_2O

Post Test

Name: ________________________________

Class: ________________________________

Marks: ________________________________

Instructions: Every equation below is unbalanced. Write the balanced version in the blank spaces.

1. ___ H_2 + ___ O_2 → ___ H_2O

2. ___ K + ___ Cl_2 → ___ KCl

3. ___ HCl + ___ NaOH → ___ NaCl + ___ H_2O

4. ___ $Ca(OH)_2$ + ___ H_3PO_4 → ___ $Ca_3(PO_4)_2$ + ___ H_2O

5. ___ Na + ___ B_2O_3 → ___ Na_2O + ___ B

6. ___ C_2H_4 + ___ O_2 → ___ CO_2 + ___ H_2O

7. ___ $Pb(NO_3)_2$ → ___ PbO + ___ NO_2 + ___ O_2

8. ___ C_4H_{10} + ___ O_2 → ___ CO_2 + ___ H_2O

9. ___ $FeBr_3$ + ___ H_2SO_4 → ___ $Fe_2(SO_4)_3$ + ___ HBr

10. ___ $KClO_3$ → ___ KCl + ___ O_2