INTERACTIVE AUGMENTED REALITY AIDED SOFTWARE FOR PHYSICS EDUCATION USING EXPLORATORY APPROACH

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Software Engineering with Honours

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SEPTEMBER 2023

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"INTERACTIVE AUGMENTED REALITY AIDED SOFTWARE FOR PHYSICS EDUCATION USING EXPLORATORY APPROACH"** was prepared by **TAN KIA KHENG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Software Engineering at Universiti Tunku Abdul Rahman.

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ACKNOWLEDGEMENT

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Ts Dr Lee Chen Kang for his invaluable advice, guidance and his enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents and friends who had helped and given me encouragement to complete this project. The completion of this project could not have been accomplished without the support of them.

Lastly, I would like to thanks all the authors of the documentations I referred and the library I used. Their professional knowledges and selfless contributions had helped me solve many obstacles I encountered throughout the whole project.

ABSTRACT

Interactive Augmented Reality (AR) is a revolutionary technology that has gain significant interest from a wide range of industries, especially the field of education. This project explores the usage of Augmented Reality (AR) technology to enhance physics education, focusing on improve students' physics learning progress with exploratory approach. The project's objective is to develop and evaluate a software application with physics learning modules aided with Augmented Reality (AR) technology, facilitating learners to obtain knowledge. There are 4 core modules in this application includes theory, quiz, simulation and AR playground. This project was mainly developed by Unity and Vuforia. The adopted methodology of this project is ADDIE model. Both System Usability Scale (SUS) and Post-Study System Usability Questionnaire (PSSUQ) were used as the method for evaluating this application. The result of SUS showed that the application has a high level of usefulness, but there was still potential for development. Meanwhile, the result of PSSUQ showed that this application satisfies most of the respondent’s expectation in terms of information quality and system usefulness, but in term of interaction quality, it meets the mean point and remains room for improvement in this aspect.

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CHAPTER 1

INTRODUCTION

1.1 Introduction of the Project

Interactive Augmented Reality (AR) is a revolutionary technical development that has drawn significant interest from a wide range of industries, especially the field of education. In the modern day, Augmented Reality (AR) has been used to help students better assimilate their education, especially in the area of physics. The use of Augmented Reality (AR) technology improves students' learning experiences by promoting greater levels of immersion and engagement, which leads to improved understanding of complex physics ideas. This project will create a software with a physics learning topic and an AR puzzle environment section allows learner to use the knowledge learn from the topic to solve puzzle.

The project aims to evaluate the efficacy as well as the acceptance of interactive augmented reality-aided software in the context of physics education. Through the use of Augmented Reality (AR) technology, the program was developed with the goal of giving students with an interactive and explorative approach to understanding the core concepts of physics. An exploratory technique is implemented to assess the software's effectiveness in improving students' learning results. The previously mentioned educational approach encourages students to freely explore and expose physical topics through a flexible and unrestrained method of learning.

1.2 Background Study

1.2.1 The Evolution of Physics Education

Physics education has changed significantly over time, moving away from the conventional lecture and textbook-based approach and towards more participatory and technology-driven approaches. In the past, physics instruction mostly consisted of lectures and textbooks that gave students factual data, rationales, and descriptions of natural occurrences. However, laboratory scientific education was established in the United States in the 19th century, allowing students to take part in physics experiments and put their knowledge of the subject under real-world conditions (Meltzer and Otero ,2015).

In the 20th century, physics education shifted towards a more active learning approach, incorporating group work and problem-solving sessions to encourage student participation in the learning process (Laws, Sokoloff, and Thornton, 1999). This approach emphasized the role of students as active participants in the learning process, rather than passive recipients of information (Hake and Richard, 1998).

In recent years, with the advancement of technology, there has been a growing trend of incorporating technology into physics education. Innovative tools such as simulations, interactive visualizations, and online resources have enabled students to engage with physics concepts in new and exciting ways (Wolff,1991).The emergence of Interactive Augmented Reality (AR) technology has created new possibilities for enhancing the learning experience of physics students, by providing them with an immersive and interactive learning environment.

1.2.2 The Exploratory Learning Approach

A teaching and training method known as exploratory learning places a high priority on active learning and discovery via experimentation and exploration. With this method, instructors encourage students to take charge of their own education and engage in self-directed learning. It contrasts with didactic or lecture-based techniques, which are frequently more concerned with imparting knowledge to learners in a present and structured manner.

Exploratory learning's major objective is to assist students in developing problem-solving and generalised thinking abilities that can be used in a number of situations. This strategy places a strong emphasis on the development of abilities like critical thinking, creativity, and invention, as well as the capacity for teamwork and effective communication. Learners are urged to link ideas, spot patterns and correlations, and create their own problem-solving techniques rather than just memorising material (Anon, n.d.).

The application of exploratory learning can be seen in various fields, particularly in education. For instance, Kashihara et al. (2000) created an interactive stimulation-based learning system using an exploratory approach. Exploratory learning is especially beneficial in scientific research, where scientists must explore and investigate the natural world to develop new knowledge and understanding. By using this approach, scientists can discover new phenomena, develop new theories, and test hypotheses through experimentation.

Exploratory learning is important because it motivates learners to take an active role in their own learning process. This approach allows learners to develop their own learning strategies and take responsibility for their own progress. Additionally, learners are more likely to be motivated and engaged in the learning process, leading to better learning outcomes (DeCaro, DeCaro and Rittle-Johnson, 2015).

1.2.3 Application of ICT in education and physics aspect

Physics education is no exception of how Information and Communication Technology (ICT) use in education has changed the way we teach and learn. Many ICT resources, including platforms and applications, can improve learning and open up fresh possibilities for research and discovery. E-learning is one such platform that makes use of ICT to enable and provide educational materials and courses through the internet. Additionally, students who would not have been able to attend conventional classroom-based courses now have access to education because to distant learning. Extended Reality (XR), which combines virtual, augmented, and mixed reality technology to produce immersive and interactive experiences, is another significant component of ICT in education.

Due to their easy access to a variety of data and resources that can be utilised to enhance teaching and learning, digital libraries have also grown in significance in the field of education. Students can undertake virtual experiments and witness physical phenomena that would be challenging to perceive in a typical classroom environment with the use of multimedia materials and ICT tools like simulations and modelling software. These tools can also help students visualise and grasp complicated topics.

1.2.4 Augmented Reality

With the use of augmented reality (AR) technology, the physical environment may be enhanced in real time with digital data or virtual objects. This technology perfectly combines the physical and digital worlds, giving the user an immersive experience. Smartphones and tablets, which employ a camera and screen to superimpose virtual information onto the actual environment, are frequently used to implement augmented reality (Carmigniani and Furht, 2011). AR has a wide range of uses, including in entertainment, instruction, the military, medicine, marketing, and training. For instance, an augmented reality software can show users a 3D representation of a product or a game that includes their surroundings. Another application for augmented reality by Julier, (2001) that offers a perspective of the battlefield with information and comments for tactical use. In medicine, AR can assist doctors in cooperative surgical systems with gesture-based guidance (Wen et al., 2014).

1.3 Problem Statement

1.3.1 Challenges in visualizing physics concepts

Many college and high school students have trouble appropriately evaluating their physics lab experiences and findings. The abstract nature of physics concepts, which may not have been part of the students' prior experiences, is a difficulty since it might cause the students to form conceptual conceptions that are different from what their professors are attempting to impart(Chi and Lin, 2020). Fortunately, technology such as visualization tools can assist students in enhancing their thinking skills for abstract concepts, particularly those with no prior experience in physics (Suprapto and Nandyansah ,2021). To address this problem, the project's application will contain a simulation module with multiple real-time rendered animated 3-D model that may be utilised as visualising materials for students to better illustrate their understanding and completeness of physics knowledge.

1.3.2 Traditional methods of teaching, Passive Learning

The traditional techniques of teaching physics might result in rote memorization and passive learning, which can hinder students' ability to understand complicated ideas and reduce levels of engagement. In fact, students may find it difficult to participate in genuine experiments and may get distracted as a result(Kirstein and Nordmeier, 2007). In contrast, active learning can offer a dynamic and interesting learning experience, enabling students to take a more hands-on approach to their learning. This approach can foster a deeper understanding of physics concepts, and promote greater student engagement (Mahmood et al., 2011). This project added a theory module which include multiple multimedia material such as image, sound , text, animation and etc to make it more interesting and a quiz module to provide students with learning feedback。

1.3.3 Challenges of integrating the AR user experience in physics learning

While Augmented Reality (AR) technology has the potential to revolutionize education by providing an immersive and interactive learning experience (Yuen et al., 2011) there are several challenges that must be addressed. One significant challenge is the user experience of AR services, which is very challenging to forecast or envision (Irshad and Rambli ,2015) The effectiveness of AR in physics education relies on the ability to create a seamless integration of virtual objects and real-world environments, and to ensure that the technology is accessible to all learners regardless of their technical expertise. The project's application implemented an AR playground module with used of AR SDK feature to setup the basic of AR environment such as plane detection and object placement, then author implemented own's 3-D object interactive way, such as the touch to grab, parameter changes by collision between 3-D objects , real time rendered object's mesh animation and etc.

1.4 Solution

1.4.1 Solution for challenges in visualizing physics concepts

Students can be substantially helped in properly visualizing abstract physics ideas and concept by viewing to visual and graphic simulation aids. The author has created a learning tool that uses 3-D rendering technology to convey physics theory through simple and engaging 3-D simulations in order to solve this issue.

With the use of this technology, students may use the simulation as a model for how the physics principles actually operate, ensuring that they fully comprehend the abstract ideas.

1.4.2 Solution to overcome passive learning style in physics.

This project is focused on developing an exploratory learning environment that may motivate students to actively engage in the learning process in order to overcome the passive learning style in physics. The development of an augmented reality playground module that offers a game-like environment for student to freely explore and engage with the virtual object in the real environment. A puzzle like playground combined with the theory learn enables students to make test and play around the virtual models to further boost student engagement. Students will take an active part in their education as a result, which will improve their comprehension and memory of the subject matter.

1.4.3 Solution for Challenges of integrating the AR user experience in physics learning.

The author will focus on the AR learning process itself in order to enhance the application's user experience. One option is to include an AR playground module, this module includes puzzle and instruction. This will encourage students to interact with the virtual object content and solve the puzzle. To further ensure that students can easily browse and engage with the virtual world without feeling overwhelmed or irritated, the author will provide narrator audio to guide user in this module.

1.5 Objectives

1.5.1 To investigate the usage of augmented reality and digital media technologies in aiding the learning of Physics.

The objective of studying the usage of augmented reality and digital media technologies in aiding the learning of Physics is to gain a better understanding of the potential benefits and challenges associated with integrating these technologies in the field of education. This objective involves researching the existing AR technologies, examining case studies of successful implementations. Specifically, at least five similar application that implementing AR environment for education purpose are used in the usage investigation.

1.5.2 To design and develop the interactive AR aided software for Physics learning using exploratory approach.

The objective of designing and developing interactive AR-aided software for Physics learning using an exploratory approach is to create a comprehensive, engaging, and effective learning tool that leverages the potential of augmented reality technology to enhance the learning experience. This objective requires the development of four modules, as outlined in the project application. Specifically, there will have interactive AR and Theory modules to aided for the physics learning.

1.5.3 To evaluate the effectiveness of the learning software in supporting the learning process.

This objective focuses on evaluating the effectiveness of the AR aided software in supporting the learning process. This includes assessing the software's impact on student engagement, comprehension, and retention of Physics concepts. The evaluation will be done through user testing, surveys, and data analysis to measure the software's success in achieving its intended learning outcomes. Author used industry standard questionnaire to evaluate and measure the result of the effectiveness of the application.

1.6 Project Scope

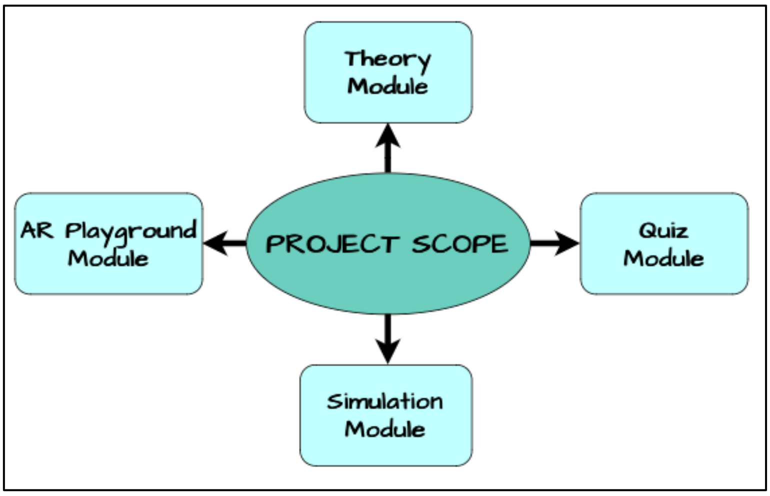


Figure 1.1 Project Scope

1.6.1 Module 1 Theory

This module is designed to provide a comprehensive understanding of the selected chapter via text, graph and etc. This module also includes module 3 simulation to demonstrate the concepts in a more interactive way. Additionally, a sub learning section is provided for chapters that include equations and practise, making it easier for users to understand and apply them. This module is developed in unity with an animated swipe pages like feature , each page contains its own text and image and element such as button ,sound effect and etc.

1.6.2 Module 2 Quiz

This module is designed to motivate the user to learn more about physics. After completing parts of the chapter, users can access the quiz environment, where they will be presented quiz question with multiple choice questions to solve and mark will be calculated and a quote will be given based on the marked.

1.6.3 Module 3 Simulation

This module offers users a unique environment designed for visualizing and understanding the underlying physics theories. Users can explore the behaviour of objects at the micro, macro, and inner perspective levels by adjusting predefined parameters. Within this environment, users can conduct experiments and explore various scenarios to gain a deeper understanding of the concepts. This module includes 3-D model rendered and animated with the mesh animation.

1.6.4 Module 4 AR playground

In this module, users can explore around with a created AR playground. In this AR playground users will be using the theory learnt in the theory module to solve the puzzle given in the environment using AR technology. The AR Playground allows users to place, interact and with the virtual object. This module offers users the opportunity to understand the physics concept in a fun, interactive and engaging way. This module will include a surface detection and placement provide by AR SDK , an interactable 3-D object ,puzzle solving flow, real time animated 3-D Object, and etc which are implemented by author

1.7 Target Audience

The target audience of this project are Malaysia high school science stream students, especially form 4 students. They are learning in classroom with textbook and teacher will introduce the topic from the textbook and student will be asked to take noted and doing assessment given by teacher. Beside normal theory class, student also having lab class to conduct experiment with the instruction of teacher.

These students will first encounter the divide from science to physics, chemistry, and biology, which are familiar but new to them. Since this is their first encounter with physics, they will be exposed to numerous new elementary physics concepts and theories. The use of AR technology for visualization purposes can significantly enhance their understanding of these concepts and make it easier for them to comprehend.

1.8 Physics Topic of this Project

The intended target audience of the project comprises students from the science stream of Form 4 level in Malaysia, whose educational program aligns with the Malaysian National Curriculum (KSSM). In accordance with the prevailing academic guideline, the curricular content of physics designated encompasses the subjects of "Measurement," "Force and Motion1," "Gravitation," "Heat," "Waves," and "Light and Optic". The author of this project will concentrate on the implementation of the syllabus related to waves.

CHAPTER 2

LITERATURE REVIEW

2.1 Multimedia technology

2.1.1 The Definition of Multimedia Technology

A presentation or programme that combines several media types, including as text, images, audio, video, and animations, is referred to as multimedia. It's high-tech because it blends contemporary computer networking technology with phonotype and videotape disposal technology, enabling it to get rid of a lot of data while producing sharp, rapid pictures (Chen and Xia, 2012) Multimedia is used in many areas, including entertainment, education, and advertising. It is employed to more fully and effectively deliver a message or convey information. Since multimedia makes it possible for consumers to have a more immersive and engaging experience, it has grown in popularity throughout time.

2.1.2 The Importance of Multimedia Technology

The importance of multimedia technology can be attributed to the fact that it makes user interaction more interesting and interactive. Due to its ability to be presented and supplied in a variety of ways and forms, multimedia technologies are essential for the facilitation of adaptive learning materials (Khamparia and Pandey, 2017). It has completely changed the way we communicate, learn, and spend the time. By providing a wealth of information in the form of words, images, and other media, multimedia in education makes learning more dynamic and interesting and enables teachers to create engaging lessons that help students understand challenging concepts (Chen and Xia, 2012). This makes it simpler for students to understand educational materials and teaching objects. The creation of video games, movies, and other forms of entertainment media has depended heavily on multimedia. Advertising products or services may be done in a more appealing and memorable way with multimedia. The use of multimedia in art has also made the merging of many media into stunning multimedia presentations attractive.

2.1.3 The Benefit of Multimedia Technology

The benefits of using many media types in a single presentation or application is that the information being communicated is more vividly and comprehensively visualised. Multimedia may provide users with a more immersive and intriguing experience, which may be very useful in education since it provides a more engaging and participatory way to learn. Students use multimedia technology to their advantage in order to study fast and efficiently (Pun, 2013). Additionally, multimedia may be used to create more engaging and interactive commercials, offering advertisers the ability to capture viewers' attention and leave a lasting impression.

2.1.4 The Example of Multimedia Technology

Multimedia applications can be seen in a variety of fields. Multimedia in education can be found in interactive classes, online courses, and instructional games for instance the quiz session with the Kahoot web application during teaching (Wang and Tahir, 2020). Multimedia in entertainment can be found in movies, and video game. Interactive adverts, social media campaigns, and digital billboards are all examples of how multimedia is employed in advertising. Installations of multimedia, digital art, and interactive exhibitions are all examples of multimedia in the arts aspect.

2.2 Augmented Reality Technology

2.2.1 The Definition of Augmented Reality Technology

An interactive experience called augmented reality uses perceptual data produced by a computer to enhance the actual environment. Digital material may be added to actual surroundings and objects with the use of software, programmes, and hardware, such augmented reality glasses. There are currently three basic types of augmented reality implementation: projection-based AR, marker-based AR, and marker-based AR without markers (Carmigniani Julie and Furht Borko, 2011). Marker-based A tangible marker, such a QR code or a picture, is used as a reference point in augmented reality (AR) to overlay virtual material. The augmented reality content causes the marker to appear on top of itself when the camera identifies the marker. To provide customers a more participatory experience, this kind of AR is frequently employed in marketing and advertising. A physical marker is not necessary for marker-less AR to function as a reference point. Instead, it detects and tracks real-world objects and surfaces using computer vision technology, enabling virtual information to be superimposed on them. This kind of augmented reality is frequently employed in navigation and gaming applications. In order to provide a more immersive experience, projection-based augmented reality (AR) displays virtual material onto real-world surfaces, such walls or floors (Carmigniani Julie and Furht Borko, 2011). AR of this kind is frequently utilised in advertisements and art pieces.

2.2.2 The Importance and Benefit of Augmented Reality Technology

The importance of augmented reality resides in its capacity to increase our degree of interaction and engagement with the world around us. A full and dynamic experience is provided for consumers when real-world surroundings and digital content are combined to produce an immersive encounter that fuses reality and virtuality. The use of augmented reality in education has been praised for its effectiveness in developing interactive teaching strategies intended to improve students' understanding of difficult ideas (Yuen, Yaoyuneyong and Johnson, 2011). Gamers now have access to a more immersive and fascinating gaming experience because to the increased degree of involvement and engagement enabled by augmented reality technology.

2.2.3 The application of Augmented Reality Technology

In a variety of industries, augmented reality is used in several ways. For example, 360ed Circuit is a type of augmented reality application that enables students to learn the theory and components of electronics. Augmented reality offers a promising opportunity for the development of interactive curriculum materials in the field of education. Augmented reality has the potential to improve doctors' capacity to visualise and grasp their patients' medical conditions in the healthcare industry. An augmented reality application, for instance, may overlay a 3D simulation of a patient's heart organ over their physical form, providing medical experts with a greater knowledge of the underlying ailment. The gaming industry has made use of augmented reality technology to create engaging games that are immersive and interactive. Pokémon Go is a prime example of this, as it allows players to capture virtual Pokémon in actual environments (Paavilainen et al., 2017) .

2.3 Exploratory Learning Approach

2.3.1 Definition of Exploratory Learning Approach

The exploratory learning approach is an educational strategy that is characterized by placing emphasis on student-centred exploratory and experimental activities. Exploratory learning has a unique pathway that includes play, deliberate exploration, and purposeful choices (Su et al., 2011).The educational strategy under consideration involves the invitation and active encouragement of learners to immerse themselves in their surroundings and engage in experiential learning activities as a means of knowledge acquisition. Acquiring knowledge requires an iterative process that includes trying out various tactics, getting feedback from others, and reflecting on oneself. This process makes it easier to develop experience in handling challenging situations and strengthen analytical skills. Within the context of exploratory learning, the role of the instructor is to act as a facilitator rather than solely as a provider of lectures. The facilitator assumes a supportive role that involves providing resources and guidance to aid the student in inquiry-based learning.

2.3.2 Importance of Exploratory Learning Approach

Implementing an exploratory learning strategy is important for plenty of reasons. First, it encourages active learning, which has proven to be more effective than passive learning strategies (Settles, 2009). It is generally accepted that students who actively participate in their learning process are more likely to retain material and later use learned skills in practical, real-world situations. Additionally, using an exploratory approach to learning has the potential to promote the development of problem-solving skills, which are essentially necessary in the modern workforce of the twenty-first century.

Exploratory methods of learning show the ability to encourage deeper and imaginative thought (Njoo and De Jong, 1993). Students who are encouraged to experiment and explore are more likely to come up with original and cutting-edge ideas as well as potential answers. By encouraging students to be able to effectively adapt to and deal with challenges faced during the learning process, implementation of this method has the potential to create robustness in them.

2.3.3 Benefit of Exploratory Learning Approach

The use of an exploratory approach to learning offers several benefits to everyone involved in the educational process(Ben-Naim, Marcus and Bain, n.d.) . This approach's capacity to encourage a sense of ownership and responsibility for one's own learning, supporting the growth of independence and self-directed learning among students. Students have the ability to develop their own interests and passions, leading to increased motivation and participation.

Additionally, it has been demonstrated that using an experiential learning strategy supports the development and improvement of critical thinking abilities. Students may analyse and evaluate knowledge, create meaningful connections, and participate in creative thinking by taking part in exploratory learning and problem-solving activities.

2.4 Comparison of Similar Application

2.4.1 Application 1 : Big Bang AR

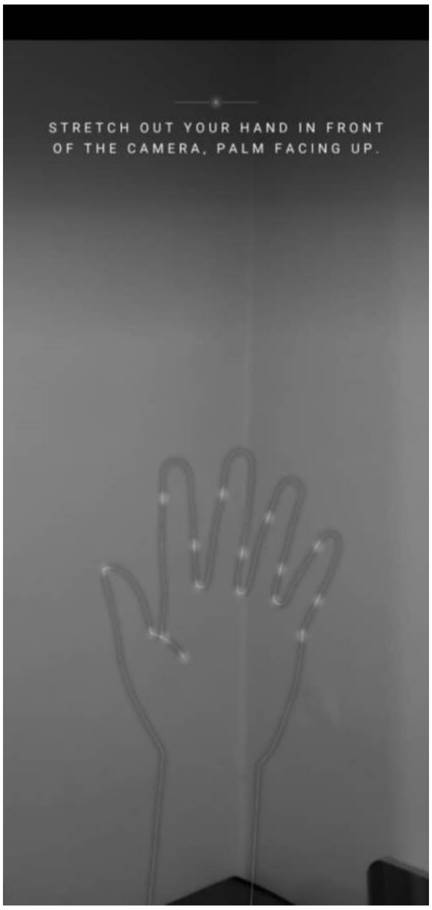


Figure 2.1 Fake Hand Gesture

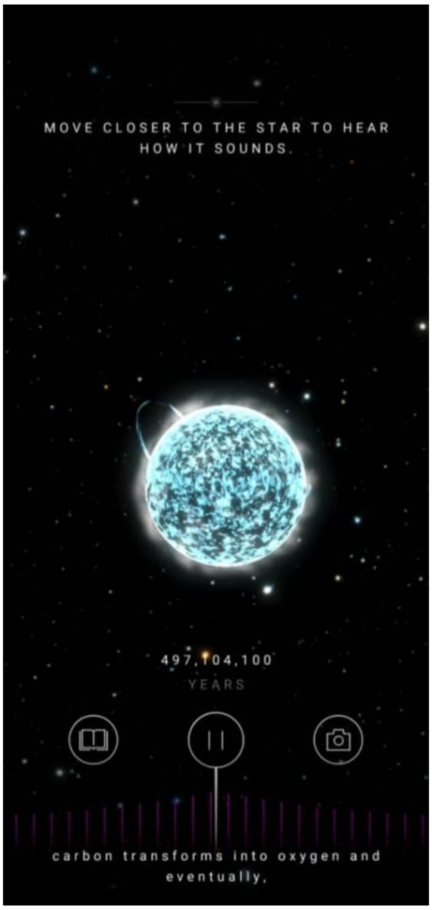


Figure 2.2 Formation of Star

A smartphone application called Big Bang AR, created by CERN and Google Art & Culture, uses augmented reality as its primary interactive method of describing the origin and development of the universe. In this application, users may learn about the Big Bang hypothesis and utilise augmented reality to experience the origin of the cosmos and stars (Figure 2.2).

Big Bang AR offers a fully immersive user experience that allows users to fully immerse themselves in the AR objects that surround them. A narrator provides instructions and describes the surroundings of the Virtual 3D models. Additionally, a fictitious hand motion instruction is used to increase user participation (Figure 2.1). The user cannot learn anything else outside of the instruction audio offered in this programme since it functions as a video presentation with everything going through a repair procedure and instructions.

2.4.2 Application 2 : Voyage AR

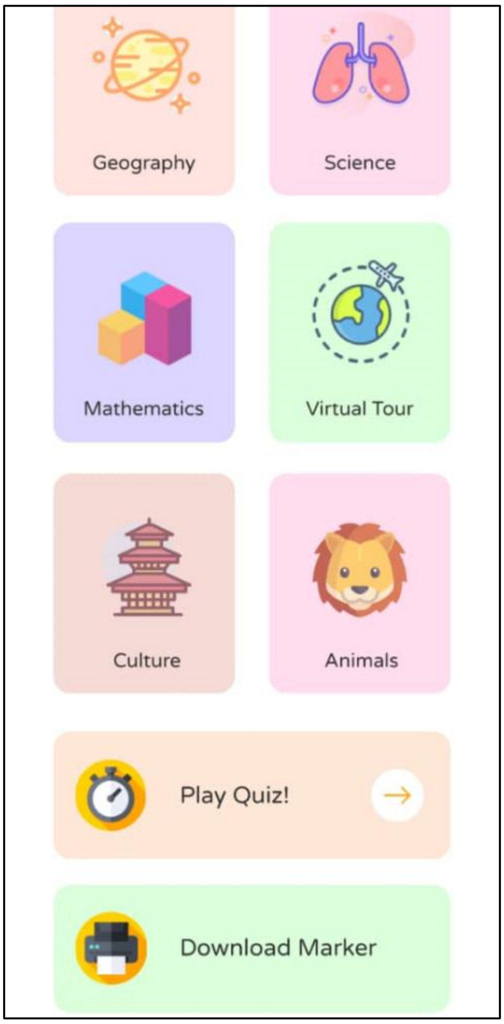


Figure 2.3 Quiz Included

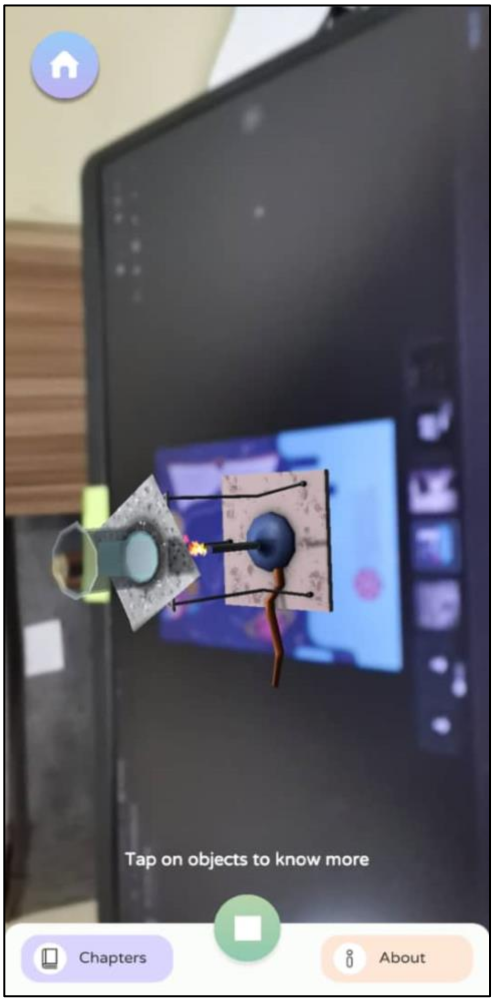


Figure 2.4 Marker Show Virtual 3D Models

Voyage AR is an example of how augmented reality technology may be used to create the educational ecosystem of the future. It is designed as a mobile application so that users may learn science topics at their own speed and in an adventurous manner by themselves.

Other than physics, this application encompasses several other sciences. In addition, Voyage AR includes quizzes in their programme to help users learn more (Figure 2.3). The marker may be easily acquired, and it is being used to display their virtual 3D representations (Figure 2.4). Since this programme focuses more on displaying demonstrations than interactive 3D virtual objects, Voyage AR also has this drawback.

2.4.3 Application 3 : Spacecraft AR

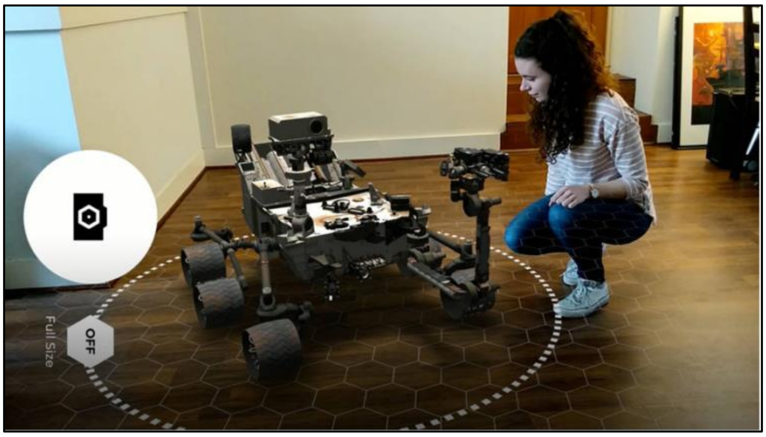


Figure 2.5 Spacecraft Demonstration in flat surface

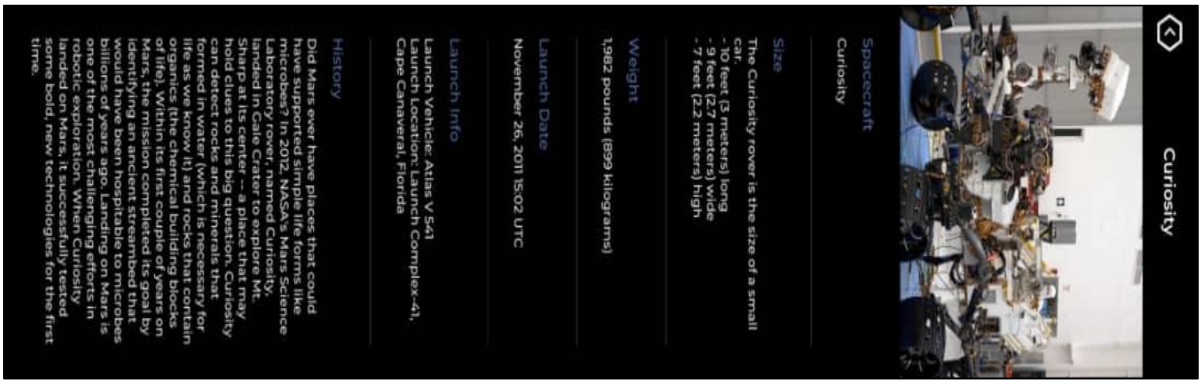


Figure 2.6 Text Based Information

A smartphone application called Spacecraft AR was created by NASA's Jet Propulsion Laboratory in Pasadena, California. It inserted virtual 3-D replicas of NASA's robotic space explorers onto any setting with a flat surface using augmented reality technology (Figure 2.5).

Basic details about the standard and the background of the spacecraft being demonstrated are available in Spacecraft AR (Figure 2.6). We could also view the virtual 3D model in 1:1 scale, but this software lacks interactivity with the object and is more focused on showing off.

2.4.4 Application 3 : Elements 4D

Figure 2.7 Show the element's appearance and info in room temperature with AR

Figure 2.8 The interaction of two different marker cube will change the AR Object

The Elements 4D application using Augmented Reality technology to demonstrate diverse chemical elements and their corresponding reactions. Its interactive design is geared towards capturing student’s attention and motivating them to learn about science and chemistry. Elements 4D using marker cube to show the elements appearance with augmented reality technology (Figure 2.7). The appearance of the elements will be change based on their chemical reaction when different elements cubes are put together (Figure 2.8).

This application has interesting interactive design that can inspire and motivate user to explore different combination of the elements, but the function of the application is just showing the appearance and the reaction equation no future knowledge provided.

2.4.5 Application 5 : 360ed's Electric Circuit AR

Figure 2.9 Game-Like

Figure 2.10 Mini Games and Quiz

360ed's Electric Circuit AR is an educational mobile application designed to facilitate the learning of electronic theories and principles through game-like tools (Figure 2.9). Using Augmented Reality technology, the application enables learners to explore the internal structure of electronic components and circuits in detail, providing an interactive and enjoyable learning experience. Additionally, learners can engage with games, quizzes (Figure 2.10), and audio features, enhancing their overall learning experience. But this application come with real-life component which is required to purchase to have the full experience of this application.

2.4.6 Application 6 : AR-physics from San Jose State University

Figure 2.11 Demonstration explains 2D motion.

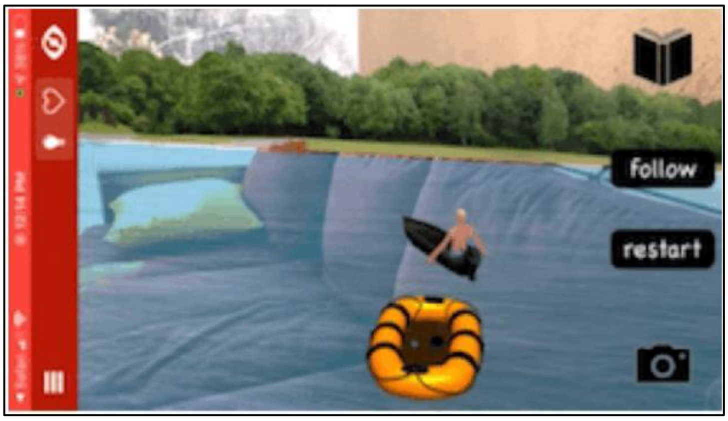


Figure 2.12 Demonstration explains relative motion.

Title	URL	Description
2D Motion	https://bit.ly/3mkQ035	Observe the motion of a rolling ball and a bouncing ball that have the same horizontal veloicty. You can observe from a reference frame moving with the balls to separate out their horizontal motion from the veritcal motion of the bouncing ball.
Bead on a Wire	https://bit.ly/2VDwHq6	Draw a path through your environment and see how a bead would slide down a wire following the same path. You can monitor the potential and kinetic energy of the bead as it slides.
Billiard Ball Race	https://bit.ly/37fEly5	Try to predict how the width of a track will affect the speed of a billiard ball as it races to the bottom.
Coherence Length	https://bit.ly/3lFMb7X	Observe the process of second harmonic generation in a crystal. You can see how dispersion and crystal length affect the efficiency.
Conservation of Angular Momentum	https://bit.ly/2VB7bSq	Move a kid in and out on a carousel to see how his changing moment of inertia affects the angular velocity of the carousel.
Crystal Lattices	https://bit.ly/39Tlc6x	Immerse yourself in a crystal and observe the various Bravais lattice unit cells that can describe the periodic structure.
Electric Charges	https://bit.ly/34caO54	Place electric charges in your environment and visualize the field lines they produce.
Electric Flux	https://bit.ly/3Ij4eyO	Visualize the flux through a ring that the user can manipulate in the vicinity of an electric dipole.
Electromagnetic Waves	https://bit.ly/3dwh0JE	Control the parameters of an electromagnetic wave and visualize the wave.
Gauss's Law	https://bit.ly/2SzSopJ	Use Gauss's law to relate the flux through a closed surface to the enclosed charge. Users can position the surface and visualize the flux through it in an effort to determine where in their environment the hidden charged are located.

Showing 1 to 10 of 33 entries   Previous 1 2 3 4 Next

Figure 2.13 Collection of AR demonstration

AR Physics is a collection of augmented reality demonstrations of physics (Figure 2.11 and 2.12) that use the Zappar app on a mobile device to present brief and engaging 3D physics tutorials and demos. Users can directly access the modules on their mobile devices through the links provided in their website table (Figure 2.13). They develop many virtual 3D models for demonstrate that cover fundamental and advance topic in physics. But they have very simple interface and lack of interaction.

2.4.7 Similar Applications Comparison Tables

Table 2.1 Similar Application Component Availability

No	Name	Audio	Background Music	Narrator speech	Simulation	Augmented Reality	Theory	Text	Video	Image	Animation	Quiz
1	Big Bang AR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
2	Voyage AR	✓		✓	✓	✓	✓	✓			✓	✓
3	Spacecraft AR				✓	✓	✓	✓		✓		
4	Elements 4D				✓	✓		✓			✓	
5	360ed's Electric Circuit AR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	AR-physics from san jose state university				✓	✓	✓	✓		✓	✓	

Table 2.2 Similar Application Strength and Weakness Table

No	Name	Weakness	Strength	From
1	Big Bang AR	-lack of detail information knowledge provided (only short paragraph provide)	-Involving fake hand gesture to interact with the application -immersive interaction -attractive interface design	https://apps.apple.com/us/app/big-bang-ar/id1453396628
2	Voyage AR	Lack of interaction between the application and the user while showing AR object	-Covers other science aspect -trigger marker can be obtained easily -include quiz -explain with audio	https://m.apkpure.com/voyage-ar-science-augmented/com.semantic.educationar
3	Spacecraft AR	-lack of interaction	-include 1:1 full size visualization	https://www.nasa.gov/feature/jpl/new-ar-mobile-app-features-3-d-nasa-spacecraft
4	Elements 4D	-simple feature, don't have further explanation or links for user to get deeper knowledge	-The interactive design can make learner having high interest to explore more.	https://www.educationalappstore.com/app/elements-4d https://apps.apple.com/us/app/big-bang-ar/id1453396628

5	360ed's Electric Circuit AR	-expensive compared to other	-Their application comes with real product that make the way of interacting to user more engaging and interesting. -include mini game and quiz to re-enforce things learn from the application.	https://www.360ed.org/products/electric-circuit-ar/
6	AR-physics from san jose state university	-simple interface, focus on demonstrate only -lack of interact with exploratory approach.	-Cover many fundamental and advance topic in physics.	https://www.sjsu.edu/faculty/beyersdorf/ARPhysics/#:~:text=AR%20Physics%20is%20a%20collection,app%20on%20a%20mobile%20device.

CHAPTER 3

METHODOLOGY AND SYSTEM DESIGN

3.1 Overview

The methodology employed in the domain of software development denotes the systematic manner of strategizing, conceptualizing, constructing, verifying, and distributing software. Several methodologies exist for software development, with distinctive benefits and drawbacks. (Table 3.1) presents a comparative analysis of different methodologies utilised in the aspect of software development. Since the project requires thorough evaluation and functionally doubles as an educational tool, the author has opted to implement the ADDIE model as the methodology for this project.

Table 3.1 Methodology Comparison

Methodology	Waterfall	Agile	DevOps	RAD	XP	ADDIE
Description	Waterfall Model	Agile Methodology	Development and Operation	Rapid Application Development	Extreme Programming	Analysis, Design, Development, Implementation and Evaluation
Approach	Sequential	Iterative	Collaborative	Iterative	Agile	Sequential
Focus	Process	Adaptability	Integration	Rapid development	Customer involvement	Emphasizes evaluation
Advantages	Clear Structure	Flexible, continuous improvement	Improve reliability and quality	quick feedback	Improves code quality and Customer-centric	Structured approach

Disadvantages	Inflexible, limited feedback	Lack structure,	Require significant investment in automation	Limited documentation	Require high skilled programmer	Inflexible, time consuming
Suitable Situations	Projects with stable requirements	Projects with evolving requirements and need for frequent feedback	Projects with a focus on continuous integration and delivery	Projects with a need for rapid development and prototyping	Projects with a small, highly skilled team and a focus on quality	Projects with a need for structured instructional design and a focus on evaluation

3.2 ADDIE Model

Figure 3.1 ADDIE Model (Crossley et al., n.d.)

The ADDIE model is an instructional design technique that has been adapted for software development. Analysis, Design, Development, Implementation, and Evaluation are the five steps that make up this process. The ADDIE model is broken down into phases, each of which has a distinct function and aids in making sure the program achieves its objectives.

3.2.1 Analysis Phase

The aim of the analysis phase is to compile data on the project, pinpoint the issue, and specify the project's parameters. This is normally accomplished by carrying out a requirements study, determining the target market, and setting the software's goals and objectives. This step also includes evaluating any current technology, resources, and limitations that could have an influence on the creation of the program.

In the Analysis phase of this project, the author conducted a thorough research of similar products and a comprehensive literature review to identify the strengths and weaknesses of existing software and application. In this phase, the problem statement and objectives of the software development project are established to ensure that the software addresses the identified gaps and meets the needs of the target audience.

3.2.2 Design Phase

The software's instructional and graphic designs are created during the design process. This entails drawing out a thorough blueprint of the software's architecture, functionalities, user interface, and content. The user experience (UX), interface, interactions, and instructional tactics that will be utilized to assist users learn how to use the program efficiently are all defined during the design phase.

In the Design Phase of this project the author creates a storyboard based on the project scope and the system flow for the application to have a clear initial demo for the software. Based on the story board a prototype of the software is built as well.

3.2.3 Development Phase

The real coding and programming are done during the development phase. This phase also entails testing the programme to ensure that any bugs are fixed before going to the implementation phase. It also involves developing the software's functionality and generating the visual design elements and integrating them into a unified system.

In the Development Phase of this project, the software is developed part by part based on the project scope’s 4 modules. Each module is separate in sub module and develop in time. Visual element such as 2-D, 3-D animation and graphic are created accordingly ,and integrate into the software. Besides, testing of the software are also perform after each module are developed and the whole software completed.

3.2.4 Implementation Phase

The programme is deployed and prepared for usage by the target audience during the implementation phase, at this phase the software should be deploy to the right platform and should made available to the users. In this phase, the author will deploy the software to iOS platform.

3.2.5 Evaluation Phase

The efficacy and impact of the software are evaluated in the evaluation phase to see if it achieves the aims and objectives set out in the analysis phase. In order to do this, data on user input and programme usage must be gathered and analysed. Based on the findings of the assessment, software may be updated or adjusted to better serve the needs of the target audience.

In this phase, the author will perform survey and questionnaire to gather the result of the software for evaluating the effectiveness to help target audience in the learning progress.

3.3 System Requirement

3.3.1 Hardware Requirement

Table 3.2 Hardware Requirement

Hardware	**Minimum Requirement**	**Maximum Requirement**
Operating system	macOS 10.15 (Catalina)	macOS 13.2 (Ventura)
Processor (CPU)	M1 Chip	M2 Chip
Memory	8 GB	16 GB
Storage	512 GB	512 GB

3.3.2 Software Requirement

Table 3.3 Software Requirement

Elements	Type of Software	Description
Text	Notes, Microsoft word	Used for text recording, and documentation.
Graphic	Gimp	Used to create and edit graphical object
Image	Gimp	Used to edit image and photo
Visual aid	Microsoft Excel, Microsoft Power Point, Canvas, Uizard.io, Draw.io	Used to create Gantt chart, and presentation slide
Audio	TTSMaker	Used to create audio file for the project, and generate human voice
Augmented Reality	Vuforia	Used to create augmented environment
2-D Animation	unity	Used to creating 2-D animation
3-D Animation	Blender	Used for creating 3-D object and animation
Authoring tools	Unity	Used to combine all multimedia

3.3.3 Main Development Tools

3.3.3.1 Authoring Tools – Unity

Figure 3.2 Logo of Unity

The cross-platform gaming engine Unity was created by Unity Technologies. Unity Games in 2D and 3D are frequently created with it. In addition, the engine's support for a number of desktops, mobile, console, virtual reality, and augmented reality platforms has subsequently been steadily expanded. It has a variety of capabilities, such as Visual Scripting, 2-D and 3-D support, Multiplatform Support, etc., that make it an outstanding authoring tool for game and software creation.

3.3.3.2 3-D Modelling Tools – Blender

Figure 3.3 Logo of Blender

A free and open-source 3-D computer graphics application called Blender is used to create 3-D animation, 3-D models, visual effects, rendering, and other things. It contains a wide range of functions, including compositing, texturing, 3D modelling, and sculpting. The versatile and potent Python-based scripting features of Blender are well-known for enabling users to automate tedious activities and develop unique tools.

3.3.3.3 Augmented Reality Platform – Vuforia

Figure 3.4 Logo of Vuforia

With the help of the Augmented Reality (AR) platform Vuforia, programmers may create AR applications for smartphones and smart glasses. It recognises and tracks 2D and 3D targets, which can be pictures, objects, or settings, using computer vision technology. Using Vuforia, developers may create augmented reality (AR) experiences that can be used to a variety of fields, including marketing, retail, education, and gaming.

3.3.3.4 Graphic Editing Tools– GIMP

Figure 3.5 Logo of GIMP

GIMP is an acronym for GNU Image Manipulation Program. It is a freely distributed program for such tasks as photo retouching, image composition and image authoring.

3.4 System Design

3.4.1 System Flow Diagram

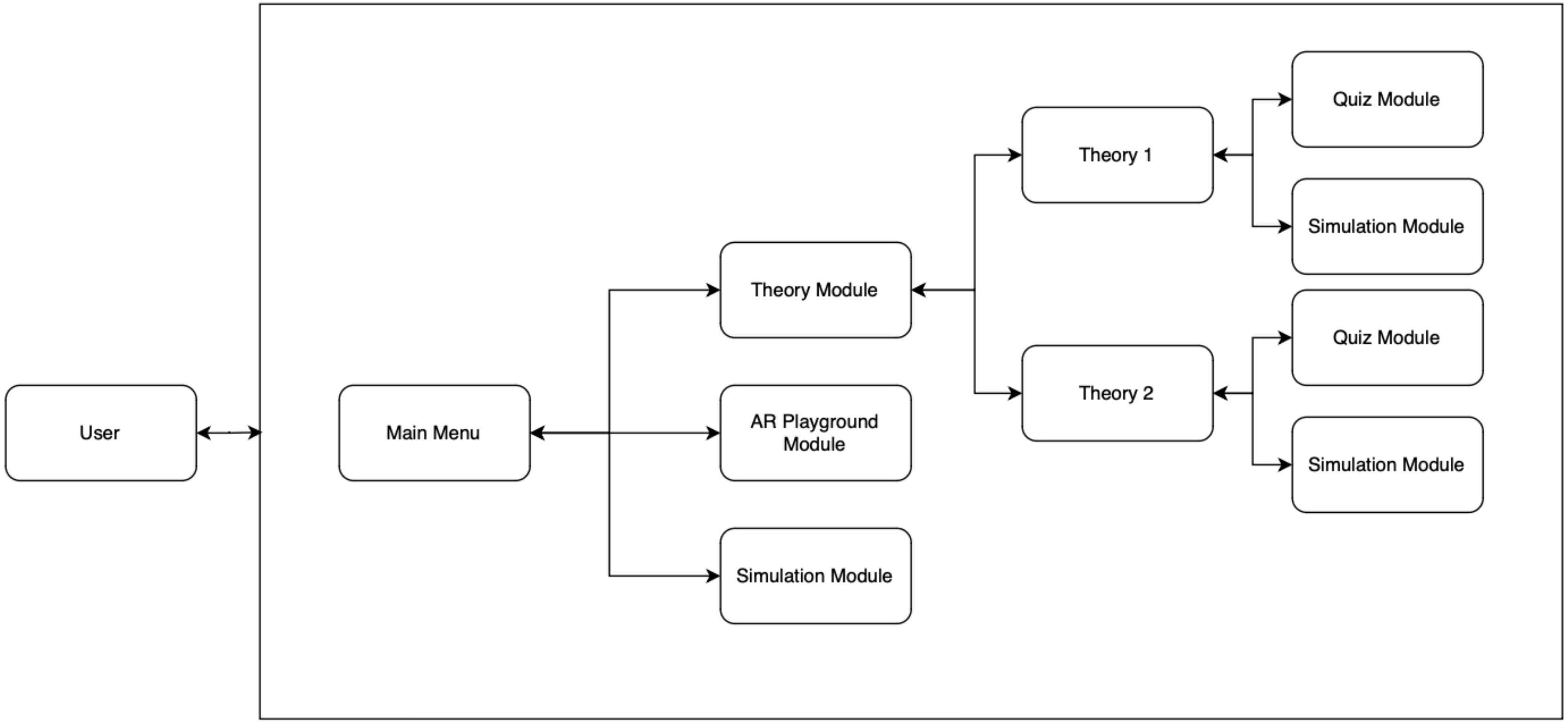


Figure 3.6 System Flow Diagram of the Project

3.4.2 Story Board

3.4.2.1 Topic: Main Menu

Story Board No: 1

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)

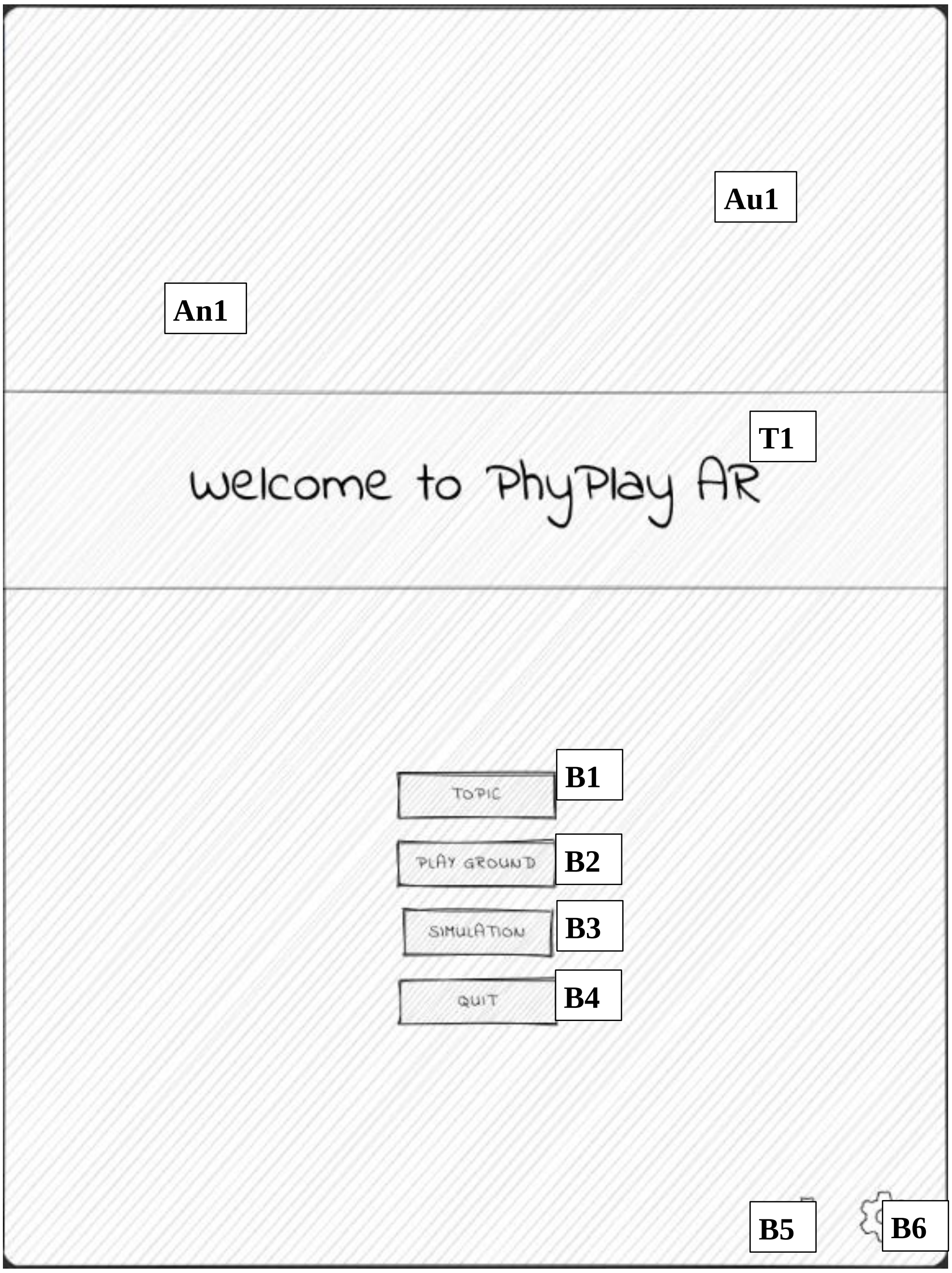
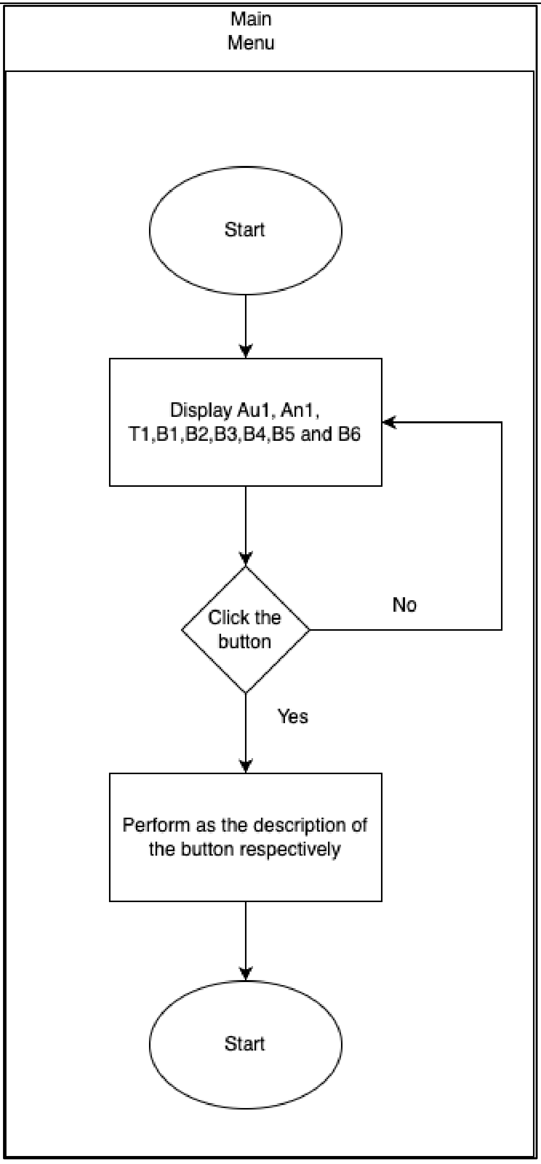


Figure 3.7 Story Board : Main Menu

Table 3.4 Story Board : Main Menu

Description	**Flow Diagram**
An1: An1 is the animation on Main Menu. **Au1:** Au1 is the background music of Main Menu. **B1**: B1 is the button navigate to topic selection page. **B2**: B2 is the button navigate to AR playground module. **B3**: B3 is the button used to quit the program. **B4**: B4 is the button used to quit the program. **B5**: B5 is the button to on or off the background music. **B6**: B6 is the button used to set user setting. **T1**: T1 is the welcome text on main menu.	

3.4.2.2 Topic: Theory Module-Topic Selection Page

Story Board No: 2

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)

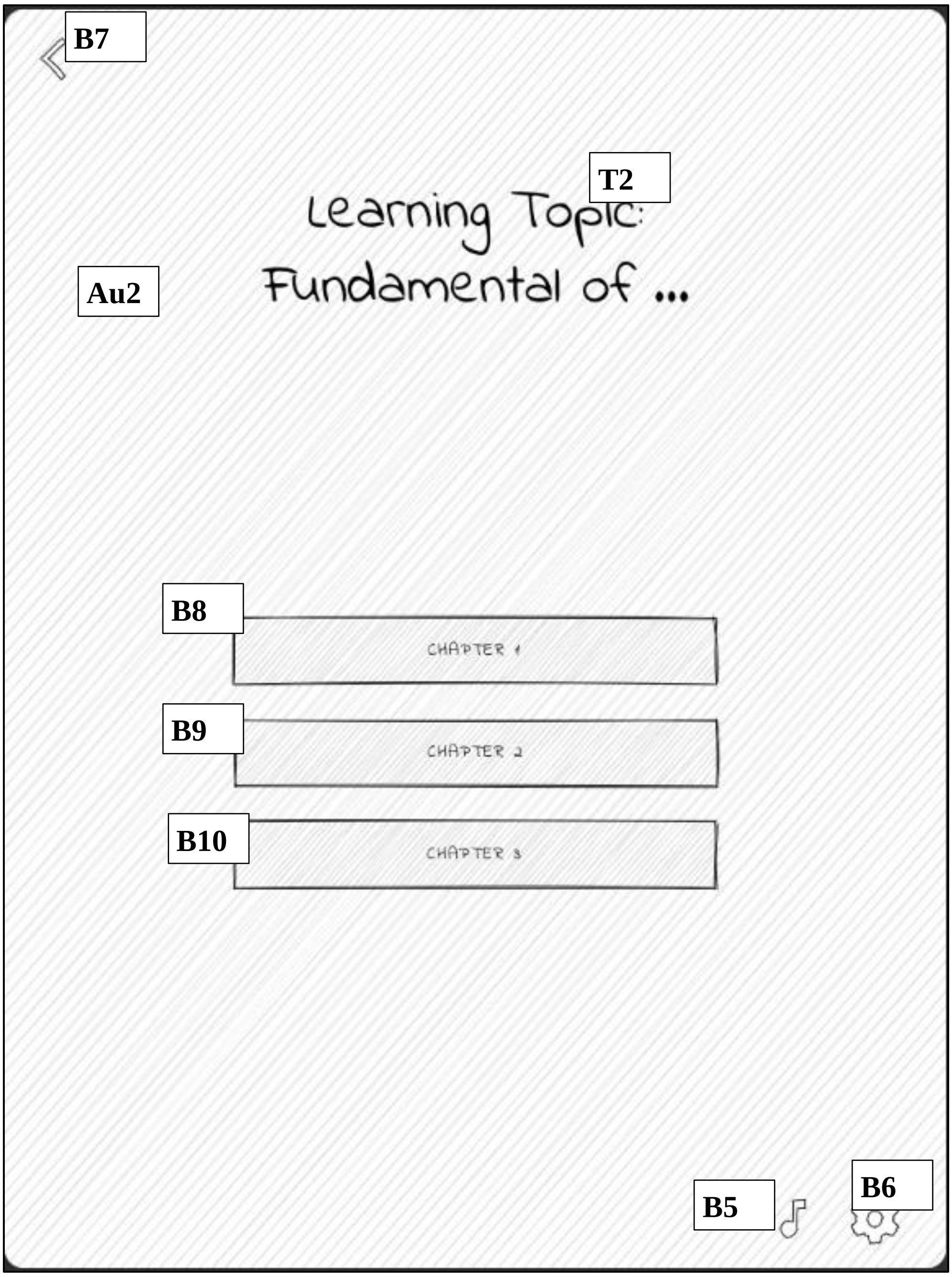
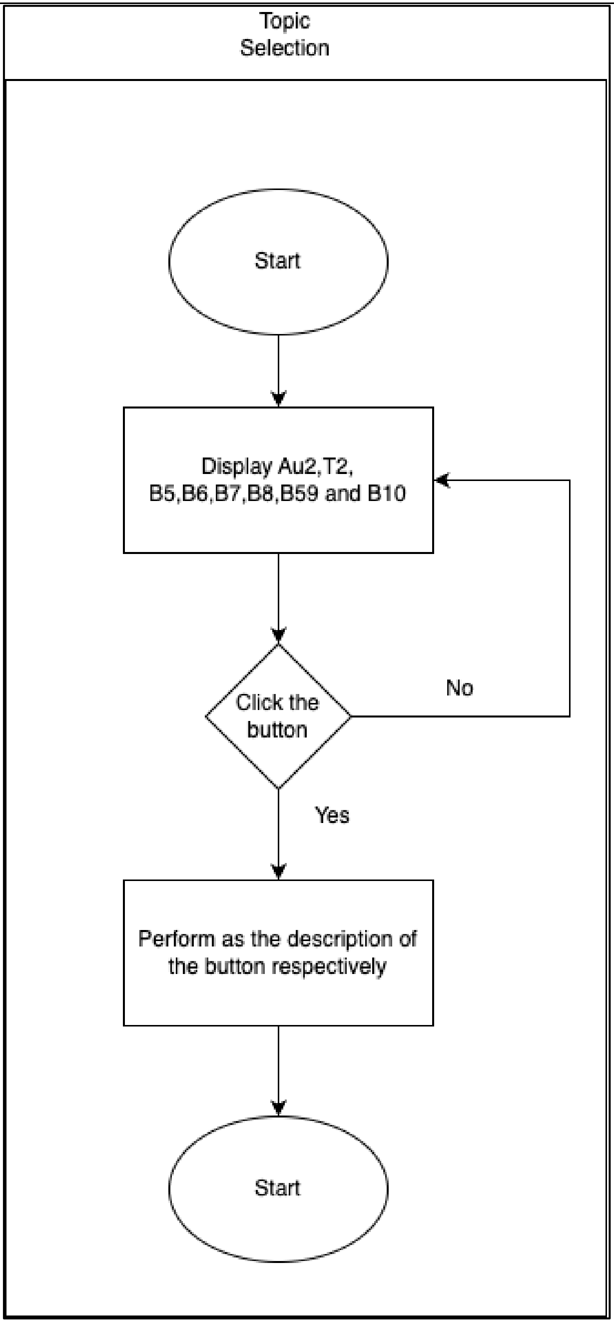


Figure 3.8 Story Board : Theory Module-Topic Selection Page

Table 3.5 Story Board : Theory Module-Topic Selection Page

Description	**Flow Diagram**
Au2: Au2 is the background music of Topic Selection Page. **B5**: B5 is the button to on or off the background music. **B6**: B6 is the button used to set user setting. **B7**: B7 is the button navigate to Main menu. **B8**: B8 is the button navigate to theory 1. **B9**: B9 is the button navigate to theory 2. **B10**: B10 is the button navigate to theory 3. **T2**: T2 is the heading text for topic selection page.	

3.4.2.3 Topic: Simulation Module-Simulation selection page

Story Board No: 3

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)

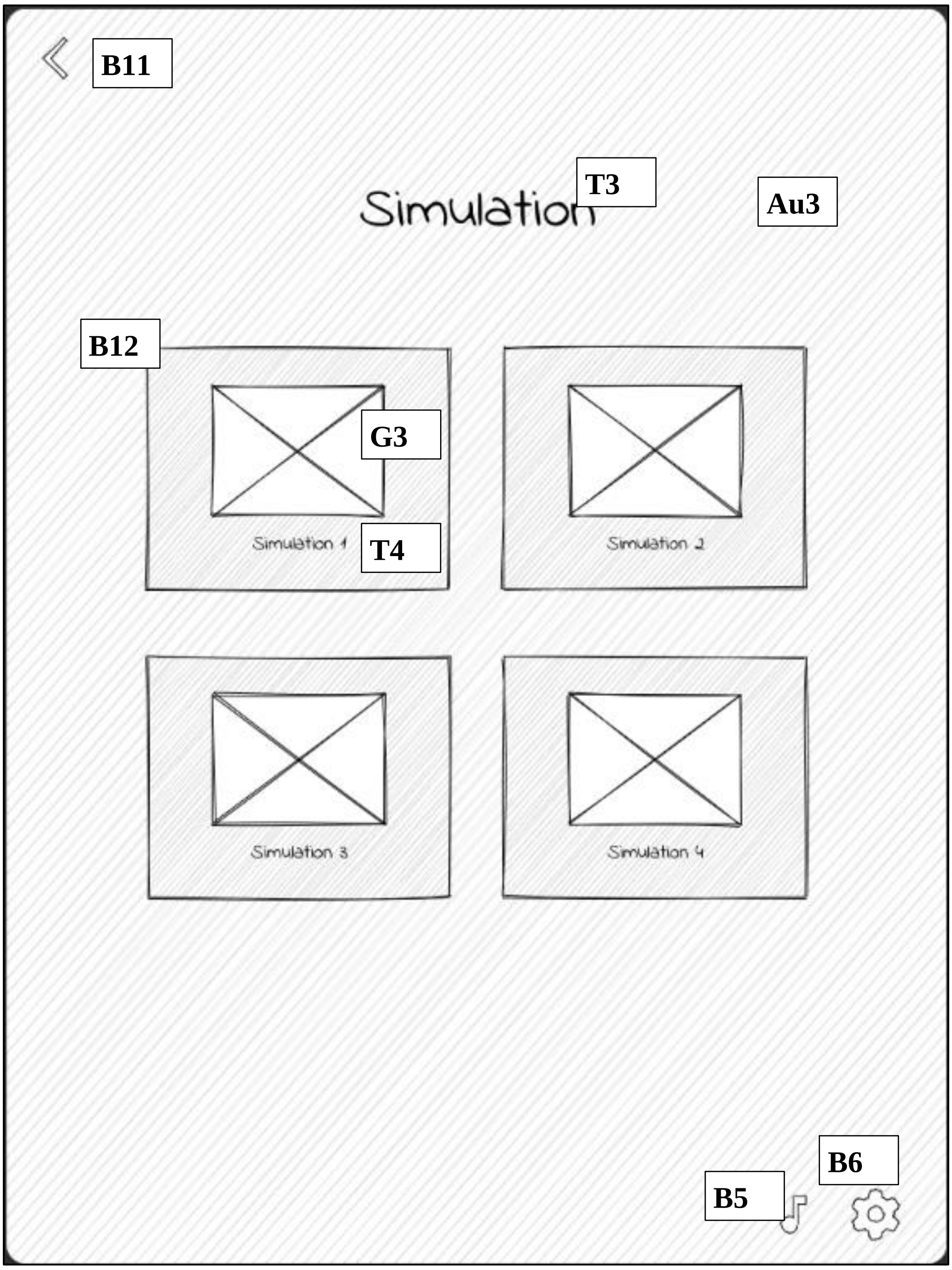
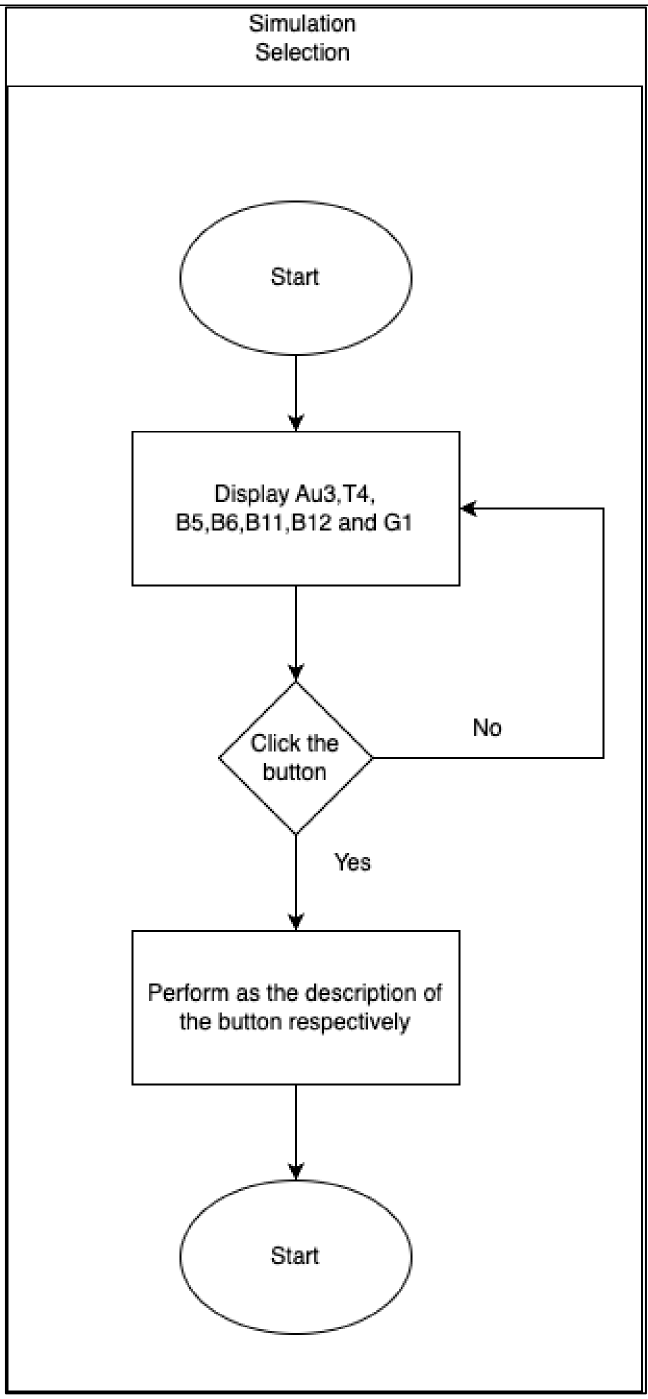


Figure 3.9 Simulation Module-Simulation selection page

Table 3.6 Story Board :Simulation Module-Simulation selection page

Description	**Flow Diagram**
Au3: Au3 is the background music of Simulation selection page. **B5**: B5 is the button to on or off the background music. **B6**: B6 is the button used to set user setting. **B11**: B11 is the button navigate to Main menu. **B12**: B12 is the button navigate to simulation 1. **G1**: G1 is the Picture of simulation 1. **T4**: T4 is the text for topic simulation 1.	

3.4.2.4 Topic: Theory Module

Story Board No: 4

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)

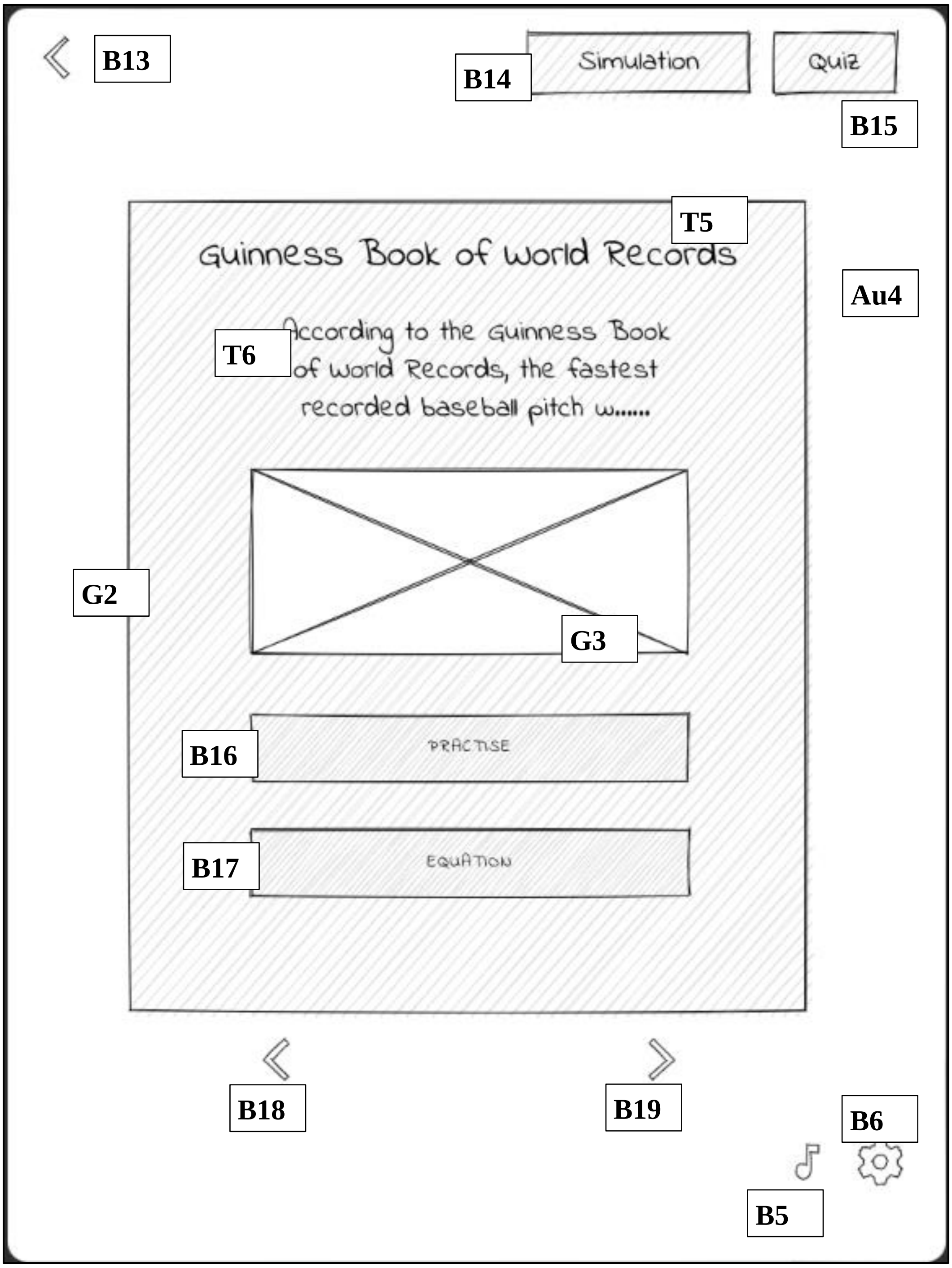
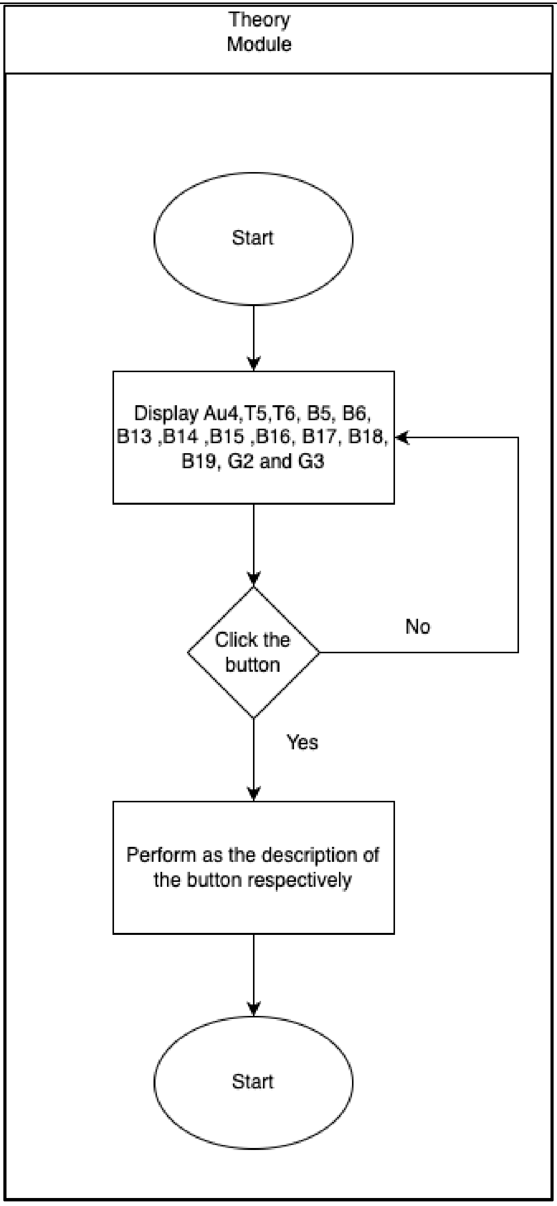


Figure 3.10 Story Board : Theory Module-Theory page

Table 3.7 Story Board : Theory Module

Description	**Flow Diagram**
Au4: Au4 is the background music of Theory Page. **B5**: B5 is the button to on or off the background music. **B6**: B6 is the button used to set user setting. **B13**: B13 is the button navigate to Main Menu Page. **B14**: B14 is the button navigate to simulation for this theory. **B15**: B15 is the button navigate to quiz of this theory. **B16**: B16 is the button navigate to the theory practice page. **B17**: B16 is the button navigate to the theory equation page. **B18**: B18 is the button navigate to previous tab. **B19**: B19 is the button navigate to next tab. **G2**: G2 is the tab contain content of current topic. **G3**: G3 is the image of current tab. **T5**: T3 is the Heading text of current tab. **T6**: T6 is the text for the theory of current tab.	

3.4.2.5 Topic: Theory Module-Theory Equation or Practise page

Story Board No: 5

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)V

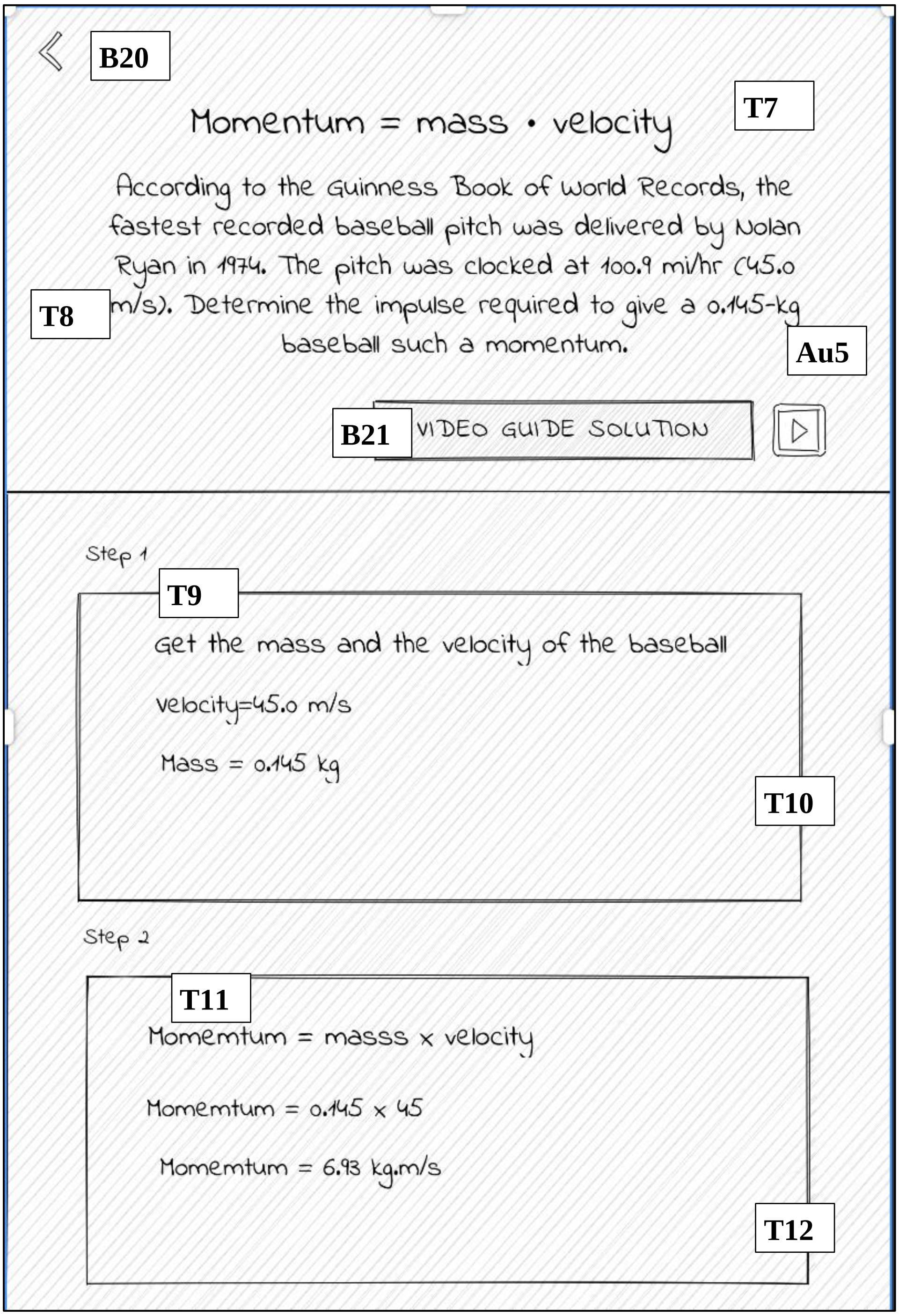
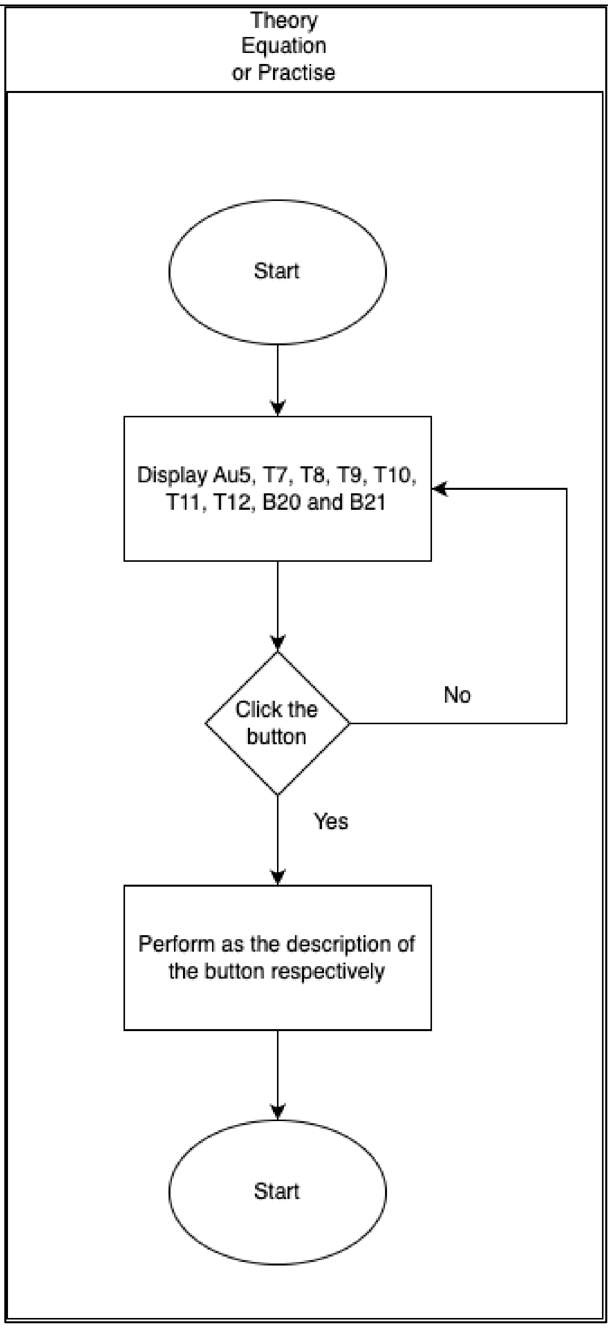


Figure 3.11 Story Board : Theory Module-Theory Equation page

Table 3.8 Story Board : Theory Module-Theory Equation or Practise page

Description	**Flow Diagram**
Au5: Au5 is the background music of Theory Page. **B20**: B20 is the button navigate to theory page. **B21**: B21 is the button navigate to the current equation solution video. **T7**: T7 is the heading text of this theory equation or practice page. **T8**: T8 is the text to display the guideline regarding the equation or practice. **T9**: T9 is the text showing the step1. **T10**: T10 is the text area that showing the detail of step1. **T11**: T11 is the text showing the step2. **T12**: T12 is the text area that showing the detail of step2.	

3.4.2.6 Topic: Quiz Module

Story Board No: 6

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video)

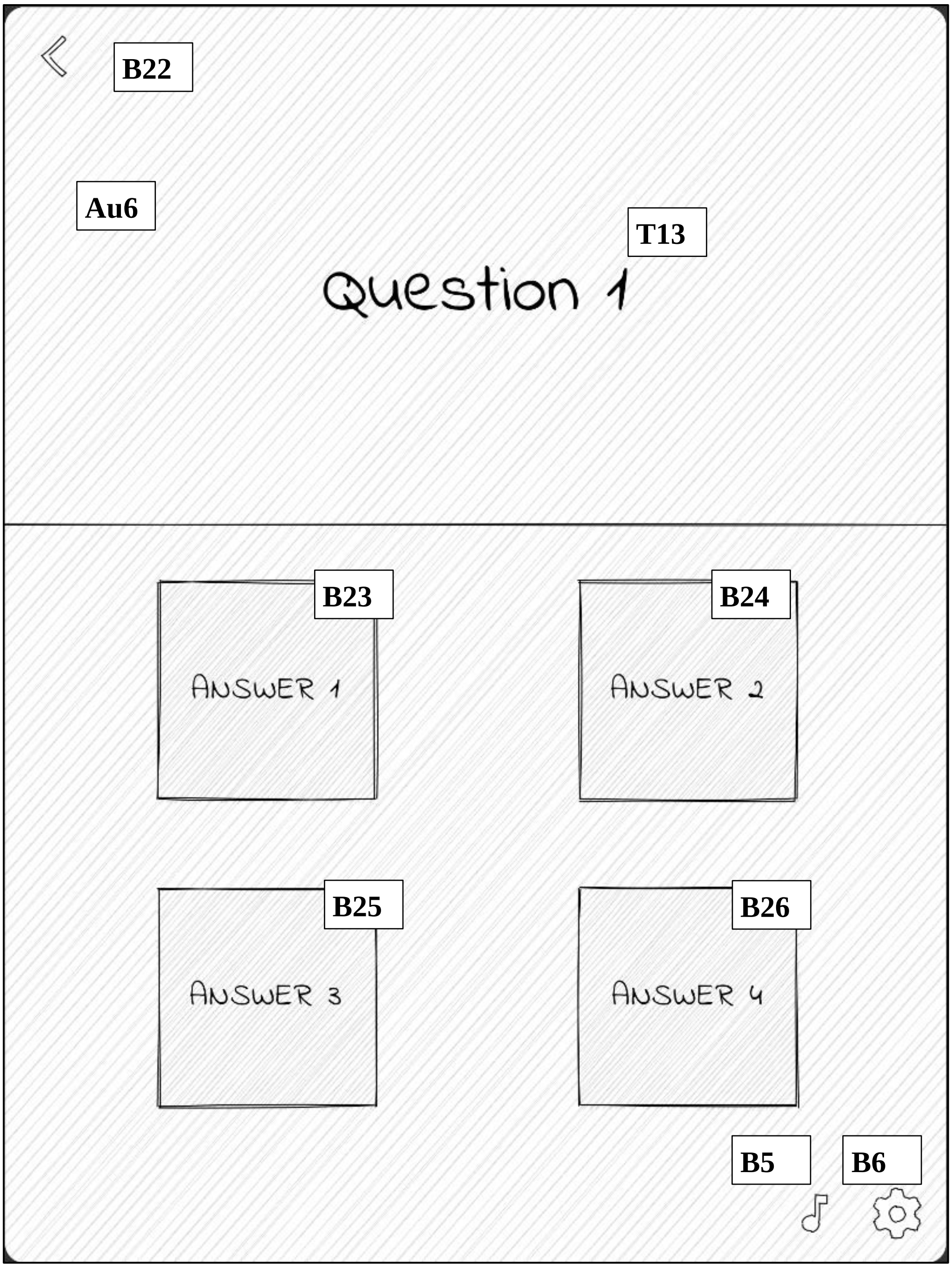
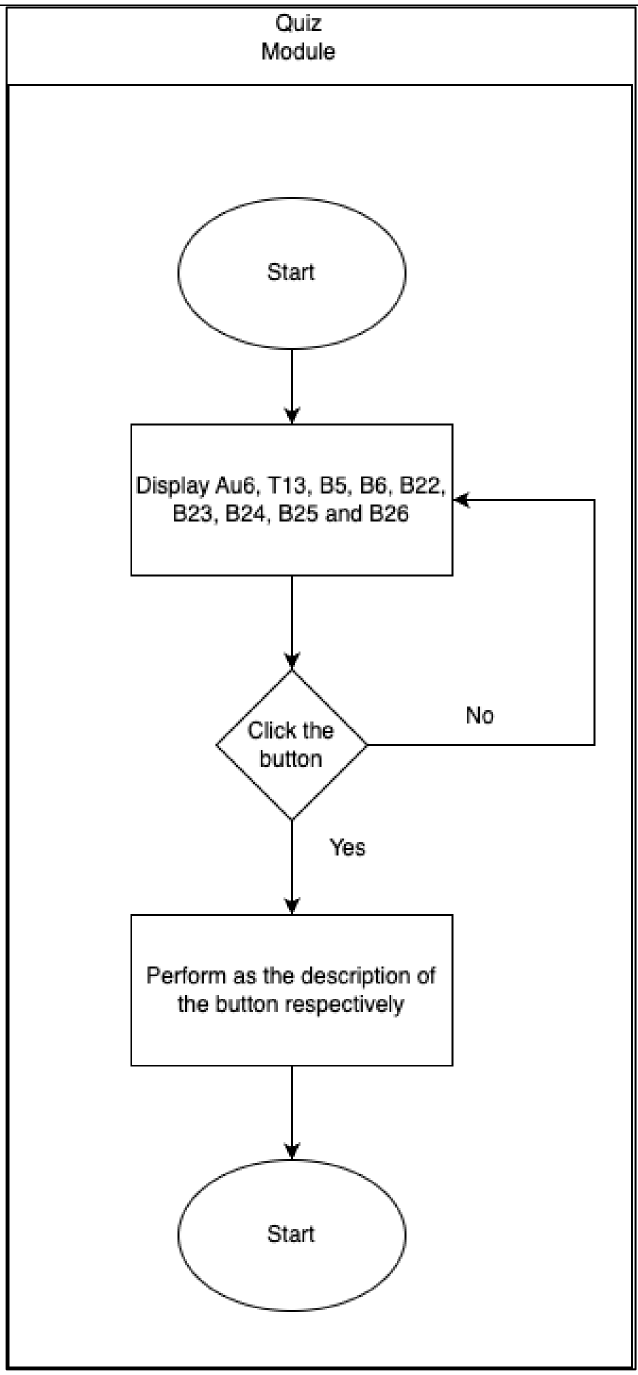


Figure 3.12 Story Board : Quiz Module

Table 3.9 Story Board : Quiz Module

Description	**Flow Diagram**
Au6: Au6 is the background music of Quiz Module. **B5**: B5 is the button to on or off the background music. **B6**: B6 is the button used to set user setting. **B22**: B22 is the button navigate to theory page. **B23**: B23 is the button to select option 1. **B24**: B24 is the button to select option 2. **B25**: B25 is the button to select option 3. **B26**: B26 is the button to select option 4. **T13**: T13 is the heading text display the Question of the quiz module.	

3.4.2.7 Topic: Simulation Module

Story Board No: 7

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video), **O**(Other)

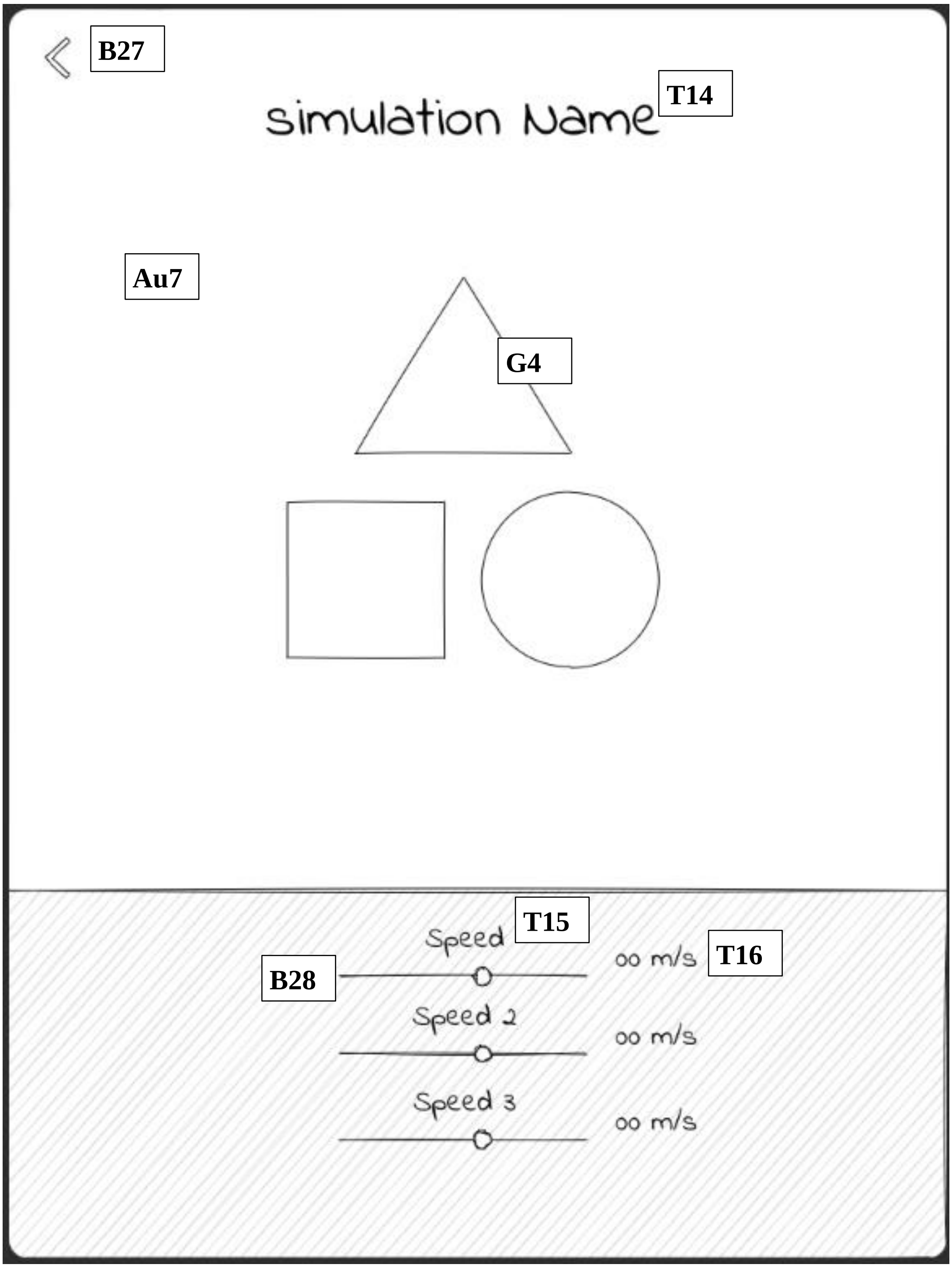
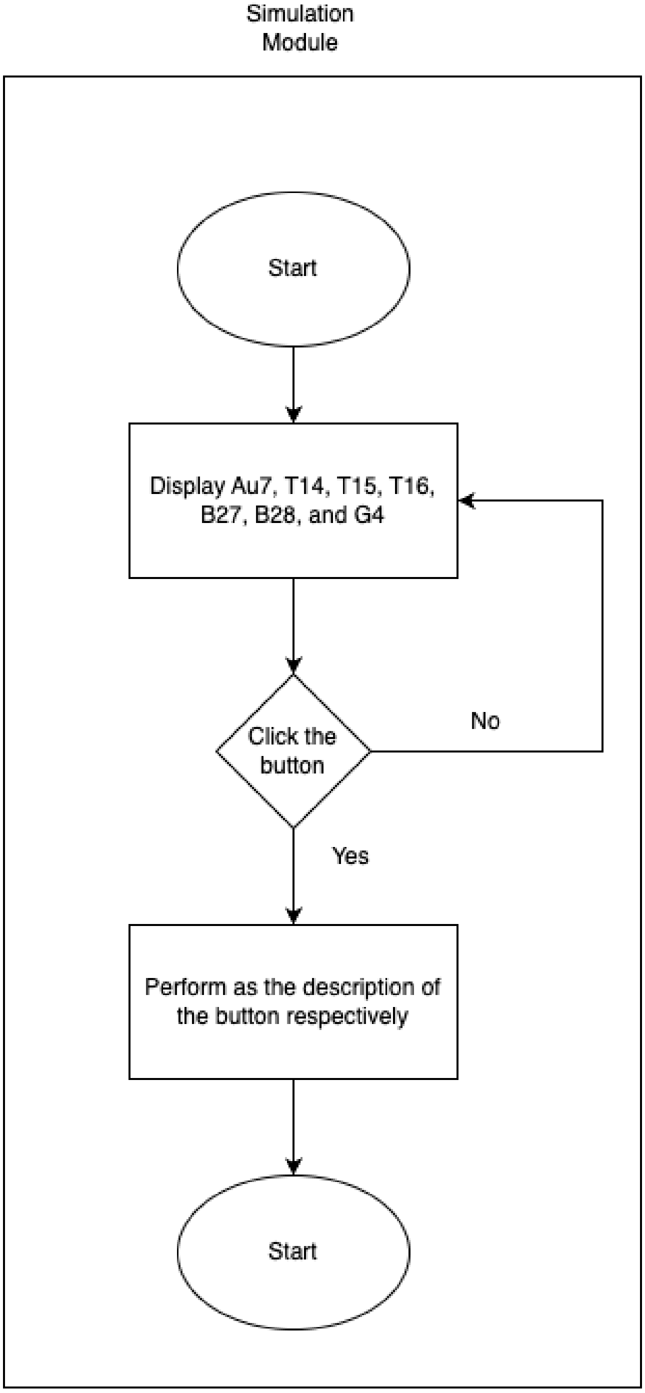


Figure 3.13 Story Board : Simulation Module

Table 3.10 Story Board : Simulation Module

Description	**Flow Diagram**
Au7: Au7 is the narrator audio of Simulation Module. **B27**: B27 is the button navigate to theory or main menu page. **B28**: B28 is the type of button design to adjust the parameter by dragging. **G4**: G4 is the 3-D simulation objects. **T14**: T14 is the heading text of this simulation page. **T15**: T15 is the text to display the adjustable parameter. **T16**: T16 is the text to display the scale and units of the parameter.	

3.4.2.8 Topic: AR Playground Module

Story Board No: 8

Component: **Au** (Audio), **An** (Animation), **B** (Button), **G (**Graphic), T**(**Text), **V** (Video), **O**(Other)

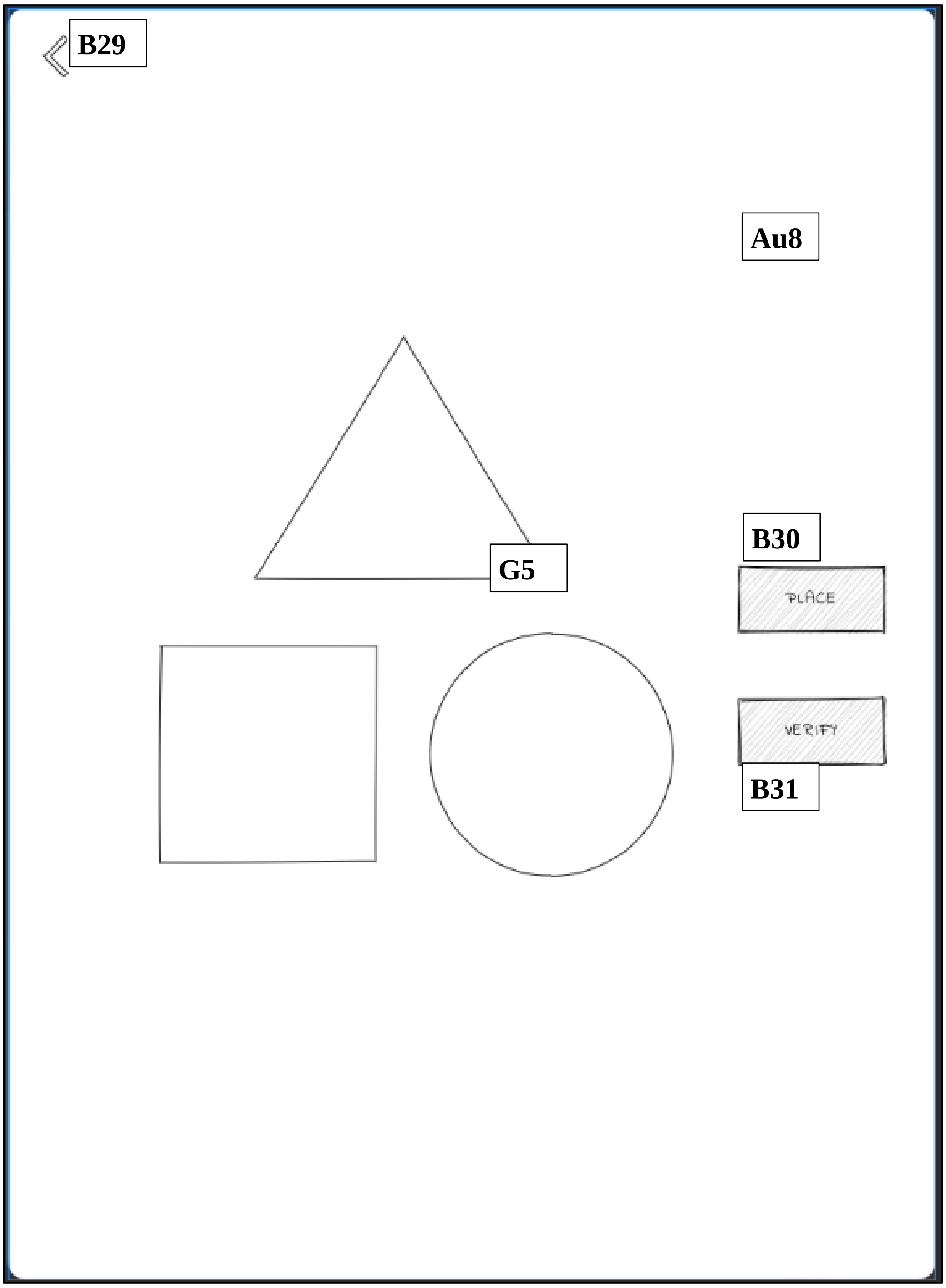
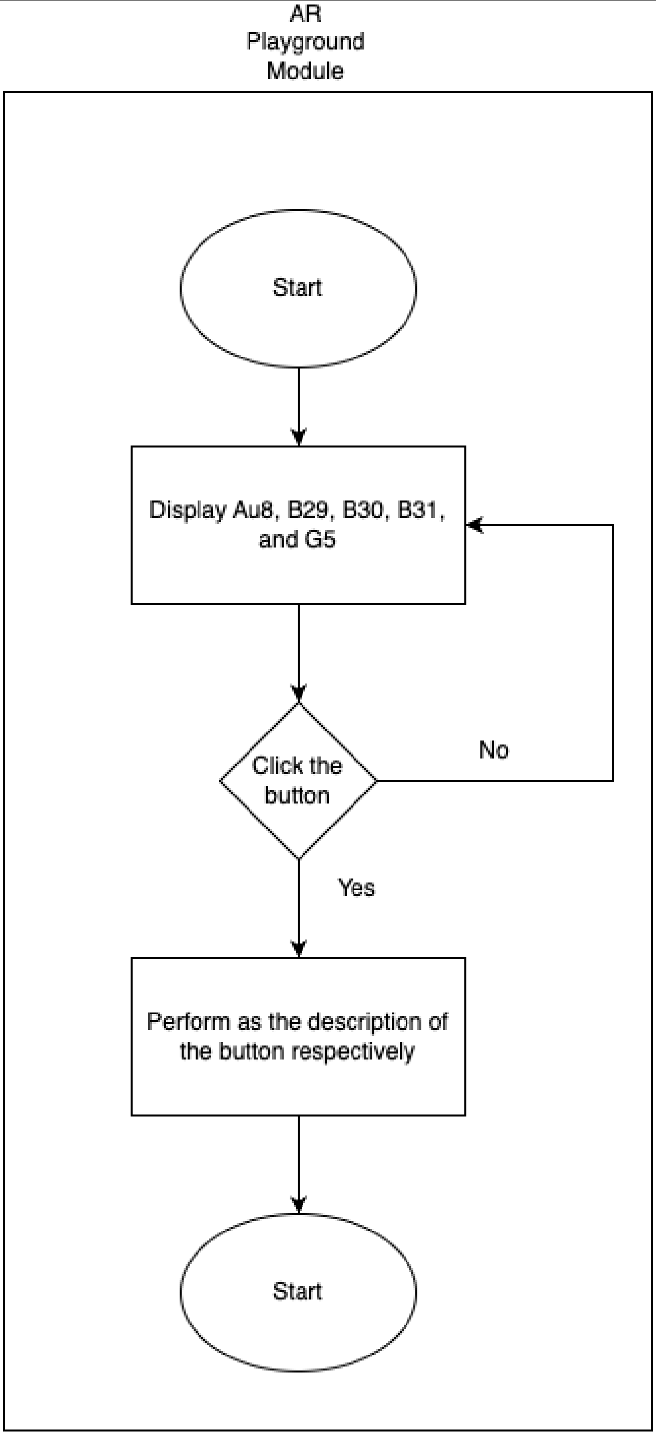


Figure 3.14 Story Board : Playground Module

Table 3.11 Story Board : AR Playground Module

Description	Flow Diagram
Au8: Au8 is the narrator audio of AR Playground Module. **B29**: B35 is the button navigate to the main menu. **B30**: B30 is the button to place the AR objects to the selected surface. **B31**: B31 is the button to **G5**: G5 is the AR Playground display area with multiple AR object.	

3.5 Project Planning

3.5.1 FYP1 Work Breakdown Structure

Table 3.12 FYP1 Work Breakdown Structure

Level	WBS	WBS Name
1	1.	Background Research
1	1.1	Problem formulation
1	1.1.1	Set problem statement
1	1.1.2	Refine problem statement
1	1.1.3	Finalise problem statement
1	1.2	Solution proposal
1	1.3	Set and finalise objective
2	2	Literature Review
2	2.1	Similar Application using AR for education
2	2.2	Project Background study
3	3	Project Scope
3	3.1	Define project scope 5 module
3	3.2	Refine project scope
3	3.3	Finalise project scope
4	4	Methodology
4	4.1	Determine project methodology ADDIE Model
4	4.2	Analysis Phase
4	4.3	Design Phase
4	4.4	Development Phase
4	4.5	Implementation Phase
4	4.6	Evaluation Phase
5	5	Requirement
5	5.1	Set software requirement
5	5.2	Set hardware requirement
6	6	System Flow Diagram
6	6.1	Design system flow diagram
6	6.2	Refine system flow diagram
7	7	Story Board

7	7.1	Design Story board
7	7.2	Refine Story board
8	8.	Prototype
8	8.1	Design Prototype
8	8.2	Refine Prototype

3.5.2 FYP2 Work Breakdown Structure

Table 3.13 FYP2 Work Breakdown Structure

Level	WBS	WBS Name
1	1.	Preparation of Development
1	1.1	Learning Unity
1	1.2	Learning Vuforia
1	1.3	Learning Blender
2	2	Development
2	2.1	System Architecture
2	2.2	Main Menu
2	2.2.1	Development
2	2.2.2	Unit testing
2	2.3	Theory Module
2	2.3.1	Development
2	2.3.2	Unit testing
2	2.4	Quiz Module
2	2.4.1	Development
2	2.4.2	Unit testing
2	2.5	Simulation Module
2	2.5.1	Development
2	2.5.2	Unit testing
2	2.6	AR Playground Module
2	2.6.1	Development
2	2.6.2	Unit testing
3	3	Implementation
3	3.1	Software Configuration

3	3.2	Software Deployment
4	4	Testing
4	4.1	Development Test Plan
4	4.1.1	SUS Testing
4	4.1.2	PSSUQ Testing
5	5	Evaluation and Result Analysis
5	5.1	End User Evaluation
5	5.1.1	User Acceptance Questionnaire
5	5.1.2	Result Analysis
6	6	Documentation

3.5.3 FYP Project Gantt Chart

FYP1 Project Schedule

Gantt Chart Template © 2006-2018 by Vertex42.com.

Project Start Date 1/30/2023 (Monday) Display Week 2

WBS	TASK	LEAD	START	END	DAYS	%	WORK
1	**Background Research**		Mon 1/30/23	Sun 2/12/23	14	100%	10
1.1	Problem formulation		Sat 2/04/23	Tue 2/07/23	4	100%	
1.1.1	Set problem statement		Sat 2/04/23	Sun 2/05/23	2	100%	
1.1.2	Refine problem statement		Mon 2/06/23	Mon 2/06/23	1	100%	
1.1.3	Finalise problem statement		Tue 2/07/23	Tue 2/07/23	1	100%	
1.2	Solution proposal		Wed 2/08/23	Fri 2/10/23	3	100%	
1.3	Set and finalise objective		Sat 2/11/23	Sun 2/12/23	2	100%	
2	**Litreture Review**		Wed 2/08/23	Sun 2/12/23	5	100%	3
2.1	Similar Application using AR for education		Wed 2/08/23	Fri 2/10/23	3	100%	
2.2	Project Backgound study		Wed 2/08/23	Thu 2/09/23	2	100%	
3	**Project Scope**		Mon 2/13/23	Thu 2/23/23	11	100%	9
3.1	Define project scope -5 module		Mon 2/13/23	Sat 2/18/23	6	100%	
3.2	Refine project scope		Sun 2/19/23	Wed 2/22/23	4	100%	
3.3	Finalise project scope		Thu 2/23/23	Thu 2/23/23	1	100%	
4	**Methodology**		Fri 2/24/23	Wed 3/01/23	6	100%	3
4.1	Determine project methodology ADDIE Model		Fri 2/24/23	Fri 2/24/23	1	100%	
4.2	Anaysis Phase		Sat 2/25/23	Sat 2/25/23	1	100%	
4.3	Design Phase		Sun 2/26/23	Sun 2/26/23	1	100%	
4.4	Development Phase		Mon 2/27/23	Mon 2/27/23	1	100%	
4.5	Implementation Phase		Tue 2/28/23	Tue 2/28/23	1	100%	
4.6	Evaluation Phase		Wed 3/01/23	Wed 3/01/23	1	100%	
5	**Requirement**		Thu 3/02/23	Wed 3/08/23	7	100%	10
5.1	Set software requirement		Mon 3/06/23	Tue 3/07/23	2	100%	
5.2	Set hardware requirement		Wed 3/08/23	Wed 3/08/23	1	100%	
6	**System Flow Diagram**		Thu 3/09/23	Mon 3/13/23	5	100%	3
6.1	Design system flow diagram		Thu 3/09/23	Sun 3/12/23	4	100%	
6.2	Refine system flow diagram		Mon 3/13/23	Mon 3/13/23	1	100%	
7	**Story Board**		Tue 3/14/23	Mon 3/27/23	14	100%	10
7.1	Design Story board		Tue 3/14/23	Thu 3/23/23	10	100%	
7.2	Refine Story board		Fri 3/24/23	Mon 3/27/23	4	100%	
8	**Prototype**		Tue 3/28/23	Sun 4/16/23	20	100%	20
8.1	Design Prototype		Tue 3/28/23	Thu 4/06/23	10	100%	
8.2	Refine Prototype		Fri 4/07/23	Sun 4/16/23	10	100%	

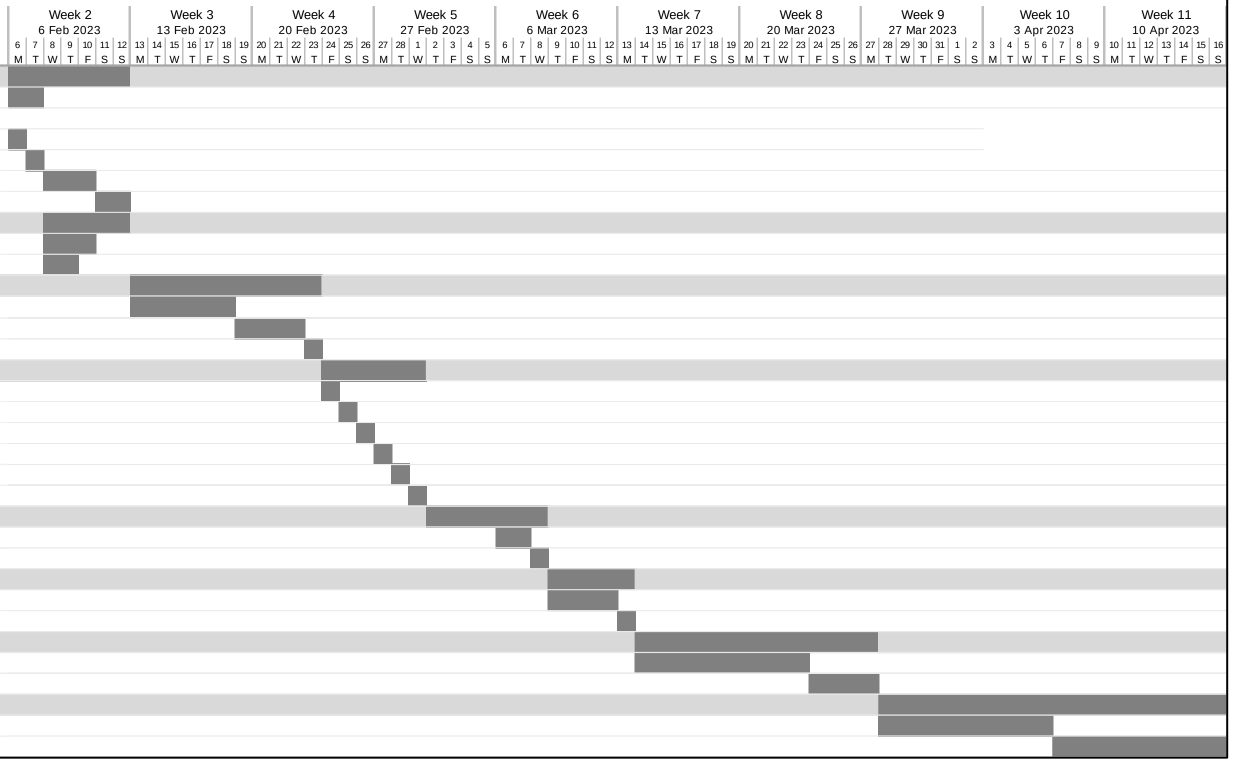


Figure 3.15 FYP1 Gantt Chart

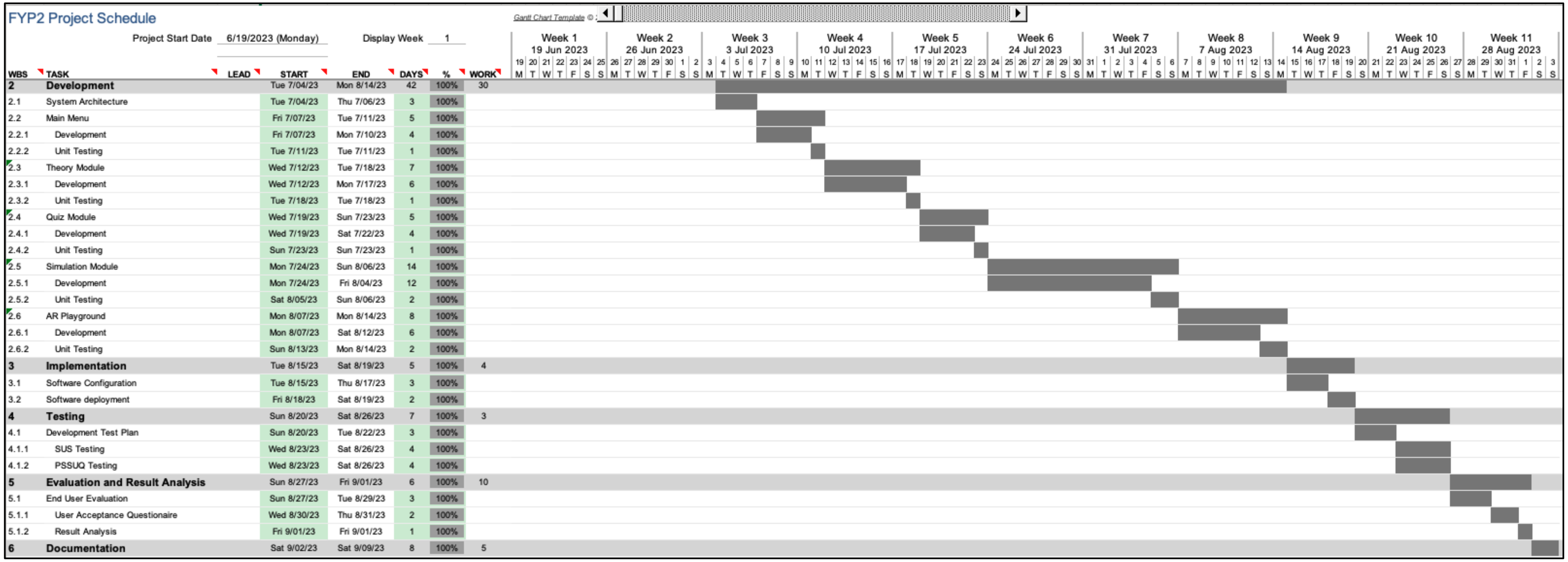


Figure 3.16 FYP2 Gantt Chart

CHAPTER 4

DEVELOPMENT

4.1 Overview

The development phase is the most important part of the project .In this project contains total 9 unity scene which are: MainScene, Theory1, Theory2, Theory3, Quiz1, Quiz2, Quiz3, Simulation1, Simulation2, Simulation3, Simulation4 and AR playground Scene. Each scene with same prefix name used the similar object hierarchy structure. In this chapter the author will describe about how all the object hierarchy structure and core modules are developed and implemented.

4.2 Development process

4.2.1 Main Menu

Below are unity's object hierarchy, in unity all object of a scene is arrange in this window(Figure 4.1).Each object can have multiple children .In Unity, all UI elements need to be children of Canvas object.

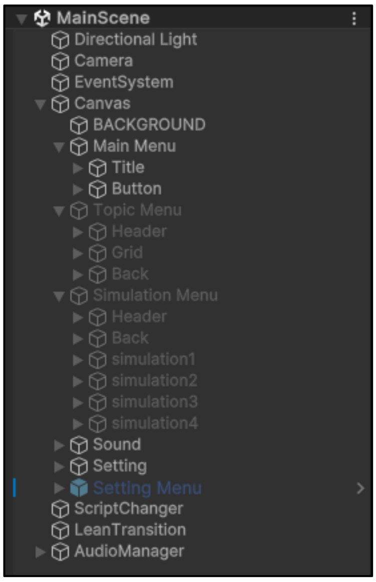


Figure 4.1 MainScene Object Hierarchy

Inside Canvas object of MainScene have 6 children which are background, Main Menu, Topic Menu, Simulation Menu, Sound and Setting, each represent the UI element being used in this scene, and those with darker colour represent they are in inactivate state which mean it will not be display, until they are activated.

Background object are the base UI that has an image inside. In (Figure 4.2) show the Unity Inspector, each object has its inspector to arrange the parameter, which user can also attach a C# script to the object.

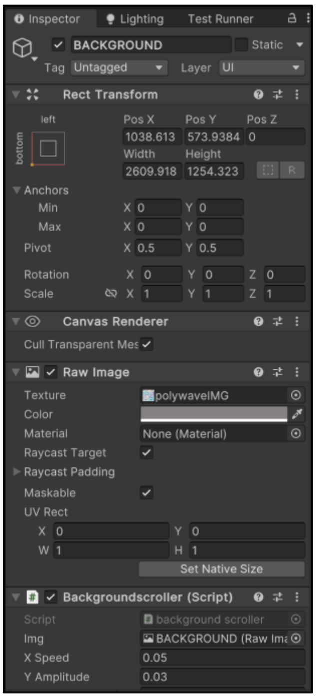


Figure 4.2 Inspector window of Background object

Figure 4.3 polywaveIMG

In the inspector of Background object ,the texture parameter under 'Raw Image' component are where the author attaches the background Image 'polywaveIMG.' (Figure 4.3) for the Main Menu page.

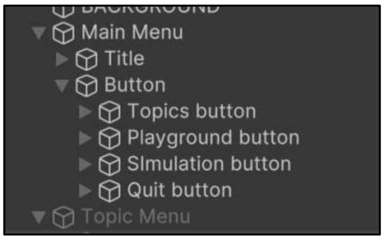


Figure 4.4 Buttons in Main Menu

Author design four button in the main menu page which are topics, playground, simulation and quit. When these buttons are clicked the action below will be perform:

Topics button: Inactivate ‘Main Menu’object and activate ‘Topic Menu’object as the On Click parameter set in inspector (Figure 4.5).

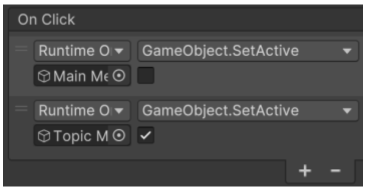


Figure 4.5 Topics button On Click

Playground button: Load AR Playground scene as the On Click parameter set in inspector (Figure 4.6).

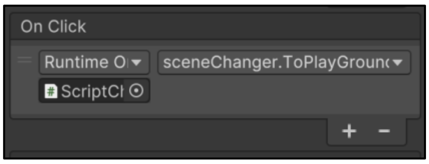


Figure 4.6 Playground button On Click

Simulation button: Inactivate ‘Main Menu’object and activate ‘Simulation Menu’object as the On Click parameter set in inspector (Figure 4.7).

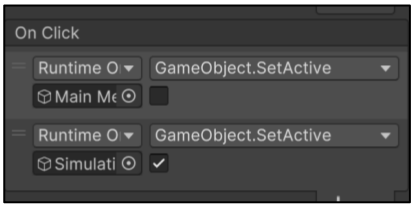


Figure 4.7 Simulation button On Click

Quit button: Quit Application as the On Click parameter set in inspector (Figure 4.8).

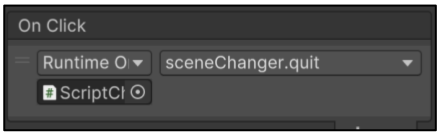


Figure 4.8 Quit button On Click

The function ‘SetActive()’ perform in Topics button and Simulation button are function pre-define in unity for set the active or inactive state of a object. For the functions perform in Playground button and Quit button functions ‘ToPlayGroundScene()’ and ‘quit()’ are function define by author in class ‘sceneChanger’ (Figure 4.9)

```
using UnityEngine;
using UnityEngine.SceneManagement;

public class sceneChanger : MonoBehaviour
{
    private string previousScene;
    // Start is called before the first frame update
    public void ToSimulationScene(int simulationNumber)
    {
        PlayerPrefs.SetString("PreviousScene", SceneManager.GetActiveScene().name);
        if (simulationNumber == 1)
            SceneManager.LoadScene(8);
        if (simulationNumber == 2)
            SceneManager.LoadScene(9);
        if (simulationNumber == 3)
            SceneManager.LoadScene(10);
        if (simulationNumber == 4)
            SceneManager.LoadScene(11);
    }

    public void ToPlayGroundScene()
    {
        SceneManager.LoadScene(7);
    }

    public void quit()
    {
        Application.Quit();
    }

    private void Start()
    {
        previousScene = PlayerPrefs.GetString("PreviousScene", "DefaultSceneName");
    }

    public void backToMainScene()
    {
        SceneManager.LoadScene(0);
    }
    public void BackToPrevioisScene()
    {
        SceneManager.LoadScene(previousScene);
```

Figure 4.9 sceneChanger class

All scenes navigation function of this project is defined in this sceneChanger class include other module scene navigation. And the number of the scene are stored in the built setting (Figure 4.10)

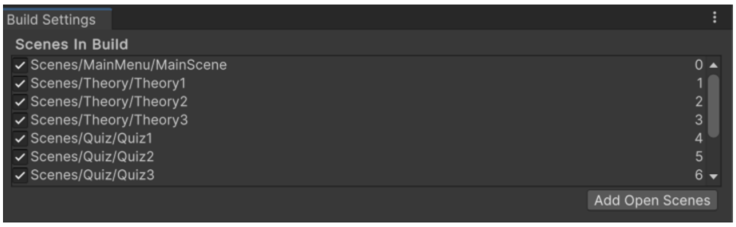


Figure 4.10 Scenes in Build Setting

Next object in MainScene is ‘Topics Menu’ (Figure 4.11) it includes 3 button which call topic 1,2 and 3, each button will used the sceneChanger class above to navigate to respective Theory Scene.

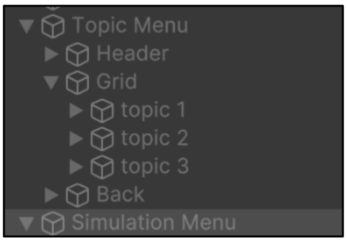


Figure 4.11 Topics Menu object

Similar as ‘Topics Menu’ object , the ‘Simulation Menu’ object (Figure 4.12) also used same method, it will navigate to the respective Simulation Scene when user click any of the four simulation button.

Figure 4.12 Simulation Menu object

Below is the screen shot of Main Menu page (Figure4.13).

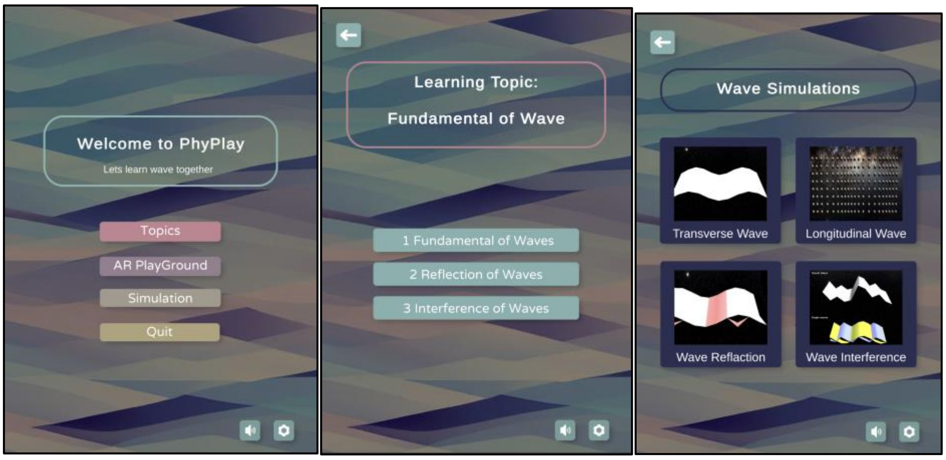


Figure 4.13 Main Menu UI (from left to right: Main Menu, Topics Menu, Simulation Menu)

4.2.2 Module 1: Theory Module

There is total 3 Theory Scene on the Theory Module, each of it using the similar hierarchy structure (Figure 4.14)

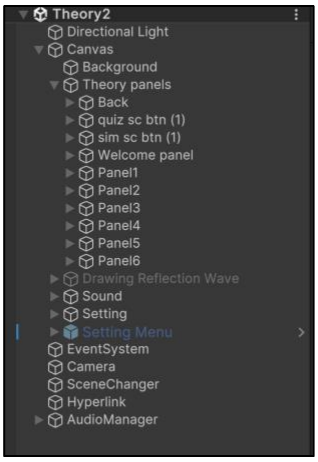


Figure 4.14 Theory Scene Object Hierarchy

Inside the Canvas object ,the theory panels are the object that contain all panels, each panel act as a page that contain the theory content including text, image and button. The first three object are general to all panel which are

Back: navigate back to the mainScene,
quiz sc btn: act as a short cut button navigate to quiz scene of this theory , and
sim sc btn: act as a short cut button navigate to simulation scene of this theory. They all are using sceneChanger class (Figure 4.9) to achieve the scene navigation.

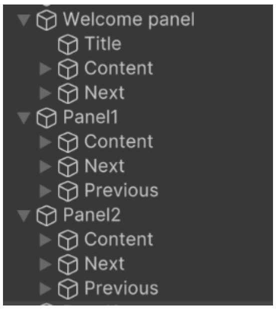


Figure 4.15 Panel object

Other than the general 3 are all panel object (Figure 4.15) which all include content object and 1 or 2 button to navigate to next and previous panel. The 'content' object is attached with theory text and have children object for image ,extra text and button. The first panel didn't have previous button and the last panel didn't have next button but a quiz button to navigate to Quiz Scene.

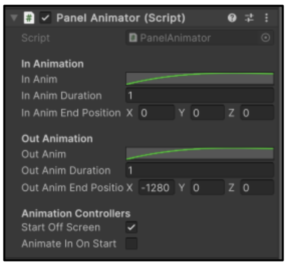


Figure 4.16 Panel Animator

Inside the panel object a script call 'Panel Animator' (Figure 4.16) is attached for creating the shifting animation when changing panel, the green curve is used to set the movement speed of the animation and the X Y and Z are used to set the end position of the UI element in the animation. At the beginning all panel are inactive except the 1st panel , when the next button is clicked out animation are perform, the next panel will be activated, and the current panel will move to the end position as the out animation set, the end position are set to outside of the screen ,and when the panel are called (when previous button are clicked) to animation in , it will move from the outside back to the original position which is x y z all equal to 0.

Below are the screenshots of Theory Module (Figure 4.17).

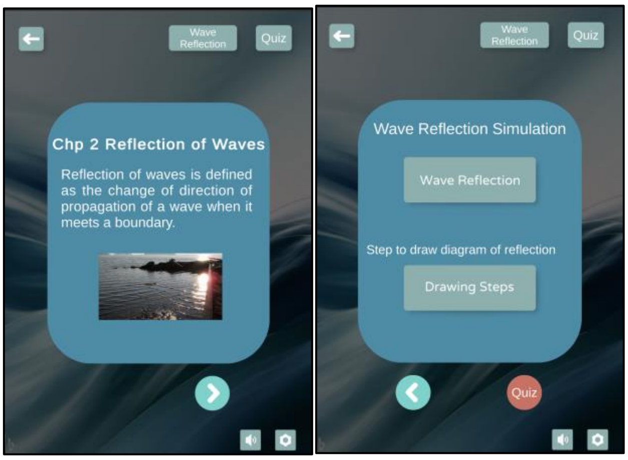


Figure 4.17 Theory Page UI (from left to right: 1st panel and last page)

4.2.3 Module 2: Quiz Module

There is total 3 Quiz Scene on the Quiz Module, each of it are navigate from respective theory and they are using the similar hierarchy structure (Figure 4.18)

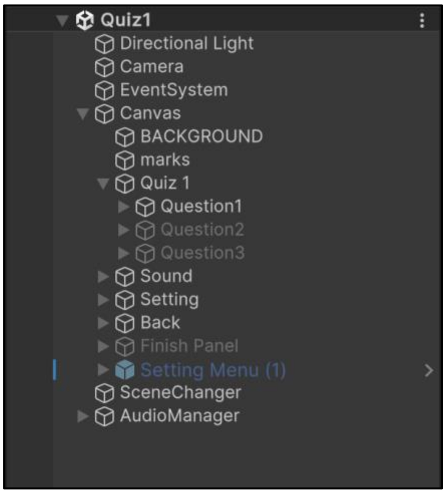


Figure 4.18 Quiz Scene Object Hierarchy

Each of the quiz contain three question and there has a 'marks' object which contain a text to store user quiz score. Beside there also has a wrong panel and a correct panel which will be activate depend on the users answer (Figure 4.19).

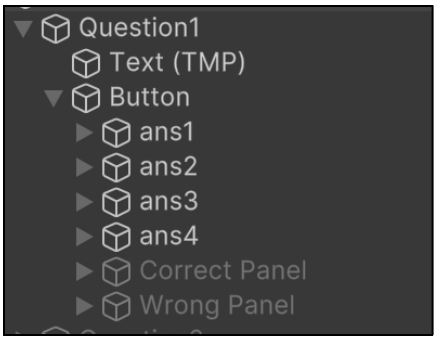


Figure 4.19 Question object

When correct answer are clicked the action (Figure 4.20) will perform, it will activate the correct panel (Figure4.21) then play a wining audio and add score to the 'marks' object achieve by the function 'increaseMark()' in quiz class (Figure 4.23). When wrong answer is clicked the action (Figure 4.20) will perform ,similar as the correct just no mark added, and wrong panel are activate

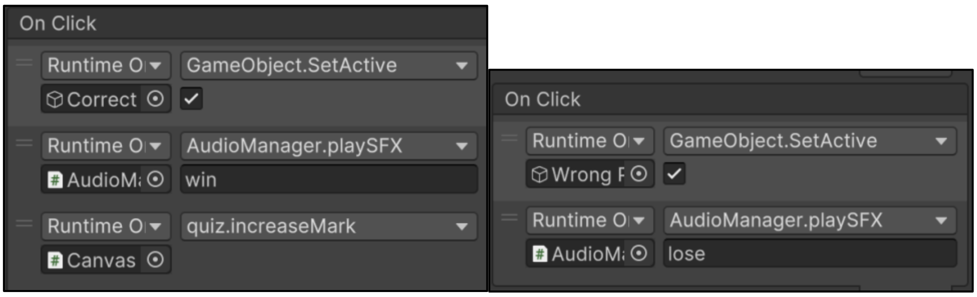


Figure 4.20 Correct and Wrong Answer On Click (left: correct, right: wrong)

Figure 4.21 Correct and Wrong Answer Panel (left: correct, right: wrong)

The continue button (Figure 4.21) in both correct and wrong panel will inactivate the panel and current question and activate the next question.

When users answer the last question , the final panel(Figure 4.22) will be activated and depend on the score in 'marks' different quote will display by the function 'finishQuiz()' in quiz class (Figure 4.23).

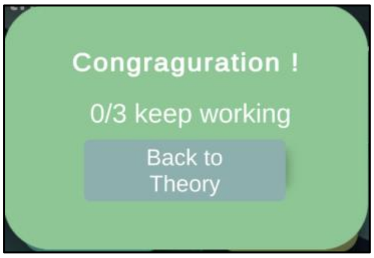


Figure 4.22 Final Panel

```
using UnityEngine;
using TMPro;

public class quiz : MonoBehaviour
{
    public TextMeshProUGUI mark;
    public TextMeshProUGUI totalmark;
    public TextMeshProUGUI Quote;

    public void increaseMark()
    {
        int currentValue = int.Parse(mark.text);
        int newValue = currentValue + 1; // Incre
        mark.text = "0"+newValue.ToString(); // U
    }

    public void finishQuiz()
    {
        if (int.Parse(mark.text) == 3)
        {
            totalmark.text = "3/3";
            Quote.text = "Excellent!";
        }
        if (int.Parse(mark.text) == 2)
        {
            totalmark.text = "2/3";
            Quote.text = "Nicely done!";
        }
        if (int.Parse(mark.text) == 1)
        {
            totalmark.text = "1/3";
            Quote.text = "Keep practicing!";
        }
        if (int.Parse(mark.text) == 0)
        {
            totalmark.text = "0/3";
            Quote.text = "You can do better!";
        }
    }
}
```

Figure 4.23 quiz class

Below are the screenshots of Quiz Module (Figure 4.24).

Figure 4.24 Quiz Page UI

4.2.4 Module 3: Simulation Module

In this project there total 4 Simulation Scene which include Transverse Wave Simulation, Longitudinal Wave Simulation ,Wave Reflection Simulation and Interference Wave Simulation ,each simulation has very different object hierarchy structure , let’s start from the first simulation transverse wave.

4.2.4.1 Transverse Wave Simulation

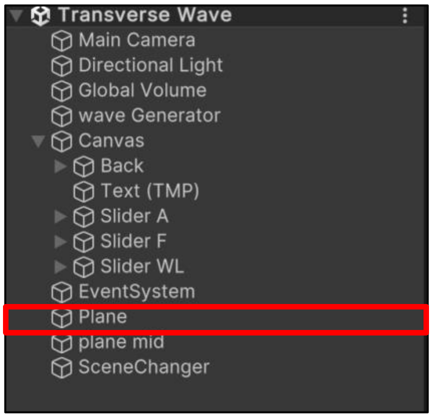


Figure 4.25 Transverse Wave Object Hierarchy

In transverse wave object hierarchy structure , the wave generator (Figure 4.26) contains the 'transverse wave generator' script with a set of parameters to create the wave motion. The parameter 'Wave Plane' is attached with the plane with red box label (Figure 4.25) , this parameter determine which object will performing the wave simulation. The other 4 parameter are the fundamental parameter of a wave.

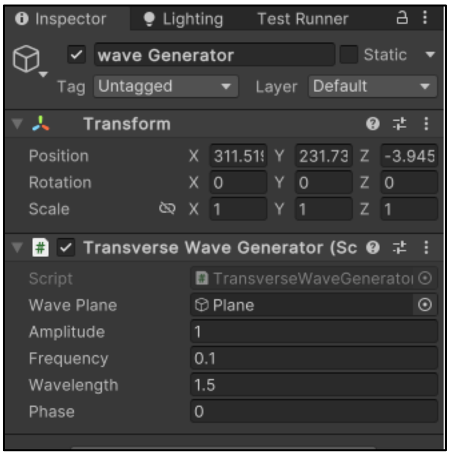


Figure 4.26 Wave Generator object

Inside 'Canvas' object contain three sliders, each of it are respective to one of the parameters in the wave generator. User can change the parameter by dragging the slider. Below is the code of wave generator (Figure 4.27) and the simulation implementation.

```
using UnityEngine;

public class TransverseWaveGenerator : MonoBehaviour
{
    public GameObject wavePlane;
    public float amplitude = 0f;
    public float frequency = 0f;
    public float wavelength = 0f;
    public float phase = 0f;

    private MeshFilter waveMeshFilter;
    private Vector3[] baseVertices;


    // Start is called before the first frame update
    void Start()
    {
        waveMeshFilter = wavePlane.GetComponent<MeshFilter>();
        baseVertices = waveMeshFilter.mesh.vertices;
    }

    // Update is called once per frame
    void Update()
    {
        GenerateWave();

    }

    void GenerateWave()
    {
        for (int i = 0; i < baseVertices.Length; i++)
        {
            Vector3 vertex = baseVertices[i];
            float waveValue = amplitude * Mathf.Sin((Time.time * frequency + vertex.x / wavelength +phase) * 2 * Mathf.PI);
            vertex.y = waveValue;
            baseVertices[i] = vertex;
        }

        waveMeshFilter.mesh.vertices = baseVertices;
        waveMeshFilter.mesh.RecalculateNormals();
        waveMeshFilter.mesh.RecalculateBounds();
    }



    public void SetAmplitude(float newAmplitude)
    {
        amplitude = newAmplitude;
    }

    public void SetFrequency(float newFrequency)
    {
```

Figure 4.27 TransverseWaveGenerator Class

The Start() function is the function that will be called when the scene starts, and the Update() function is the function will be called in every frame of the game. In start function the MeshFilter of the wave plane are assign, and base vertices of the wave plane are also assigned. In the update function the GenerateWave() function are called , this function will be called every frame of the game. In GenerateWave() function it loops all the vertices get from the wavePlane and assign the new value to these vertices by the sin function with those parameters. After assigned the vertices, it applies these changes to the mesh, recalculates normals, and recalculates the bounds of the mesh. This ensures that the visual representation of the wave is updated. The functions below such as setAmplitude() are for the sliders to update the wave parameter. Below is the screenshot of Transverse Wave Simulation (Figure 4.28).

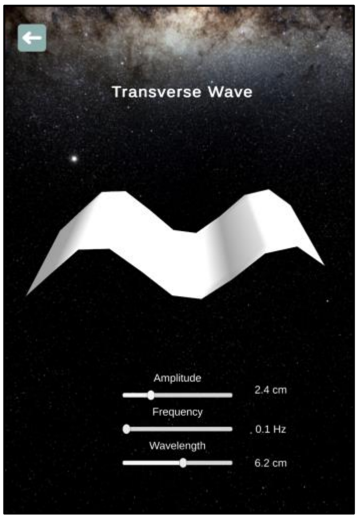


Figure 4.28 Transverse Wave Simulation Screenshot

4.2.4.2 Longitudinal Wave Simulation

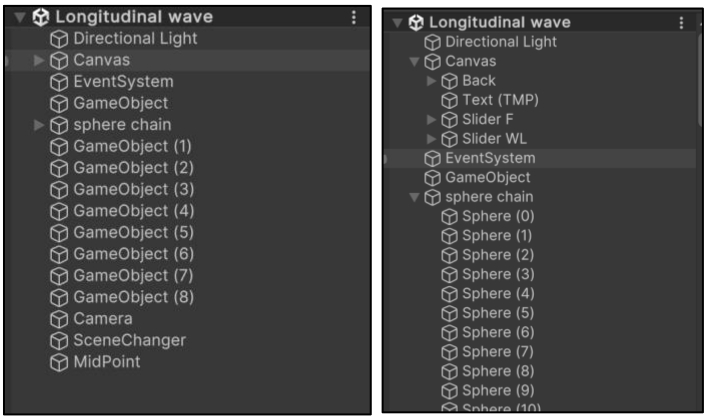


Figure 4.29 Longitudinal Wave Object Hierarchy

In longitudinal wave object hierarchy structure (Figure 4.29), the sphere chain contains all the spheres that are used for simulating the longitudinal wave ,each sphere contains a sphere controller script (Figure 4.30)which contain 2 wave parameters (frequency and Wavelength) and a wave source. The wave source is the location of the longitudinal wave start.

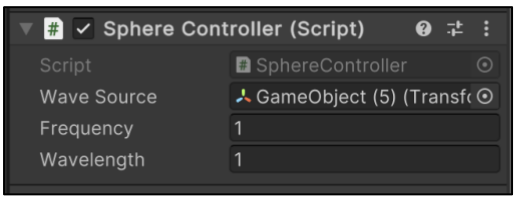


Figure 4.30 Sphere Controller component

Inside ‘Canvas’ object contain two sliders, each of it are respective to one of the parameters in the sphere controller. User can change the parameter by dragging the slider. Below is the code of sphere controller (Figure 4.31) and the simulation implementation.

```
using UnityEngine;

public class SphereController : MonoBehaviour
{
    public Transform waveSource;
    private float amplitude = 1f;
    public float frequency = 1f;
    public float wavelength = 1f;
    private Vector3 initialPosition;

    // Start is called before the first frame update
    void Start()
    {
        initialPosition = transform.localPosition;
    }

    // Update is called once per frame
    void Update()
    {
        OscillateSphere();
    }

    void OscillateSphere()
    {
        float distanceFromWaveSource = Vector3.Distance(transform.position, waveSource.position);
        float phase = distanceFromWaveSource / (wavelength * Mathf.PI);
        float waveValue = amplitude * Mathf.Sin(2f * Mathf.PI * frequency * Time.time - phase);
        transform.localPosition = initialPosition + Vector3.right * waveValue;
    }
}
```

Figure 4.31 ShpereController Class

In the starts of the scene the initial position of the sphere is assigned to a variable. The function OscillateSphere() is called every frame in the game, the distance of the sphere and the waveSource are calculated and used for determining the phase of the sphere. The waveValue calculates the offset of the sphere based on the sine wave formula with time, frequency, and phase. lastly the offset is applied to the position of the sphere as different sphere has different distance from the waveSource so it will create a longitudinal wave simulation. Below is the screenshot of Longitudinal Wave Simulation (Figure 4.32).

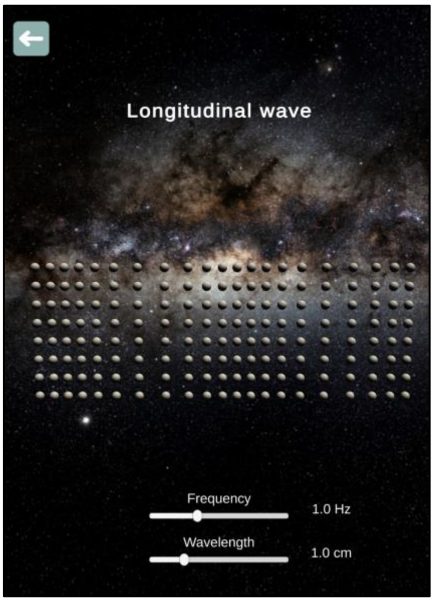


Figure 4.32 Longitudinal Wave Simulation Screenshot

4.2.4.3 Reflection Wave Simulation

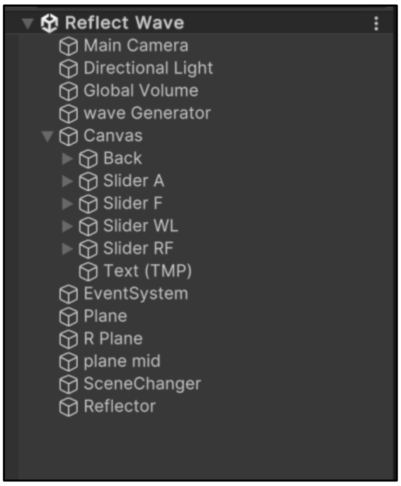


Figure 4.33 Reflect Wave Object Hierarchy

In reflection wave object hierarchy structure (Figure 4.33), it is similar with the transverse wave , the only different is that a new wave plane is added to simulate the reflected wave (Rwave Plane) , and also a block (Reflector) is added act as the reflector in this simulation (Figure 4.34).

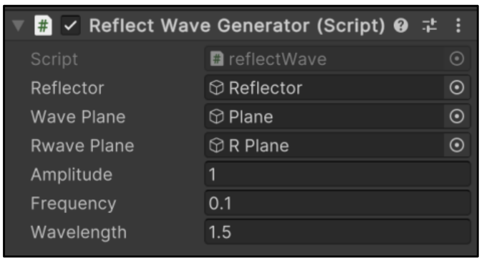


Figure 4.34 Reflect Wave Generator component

Inside ‘Canvas’ object contain four sliders, one of it represent the height of the reflector and other three respective to one of the parameters in the wave generator similar to the implementation of transverse wave simulation. User can change the parameter by dragging the slider. As most of the code implementation of reflected wave simulation is similar to the transverse wave simulation so here only describe the different. Below is the code of GenerateWave() function in the reflection wave simulation script (Figure 4.35)

```
void GenerateWave()
{
    for (int i = 0; i < baseVertices.Length; i++)
    {
        Vector3 vertex = baseVertices[i];
        Vector3 Rvertex = RbaseVertices[i];
        float waveValue = amplitude * Mathf.Sin((Time.time * frequency + vertex.x / wavelength) * 2 * Mathf.PI);
        vertex.y = waveValue;
        baseVertices[i] = vertex;

        RaycastHit hit;
        if (Physics.Raycast(vertex + wavePlane.transform.position, Vector3.right, out hit)){
            Rvertex.y = -waveValue;
            RbaseVertices[i] = Rvertex;
        }
        else
        {
            Rvertex.y = waveValue;
            RbaseVertices[i] = Rvertex;
        }

    }

    waveMeshFilter.mesh.vertices = baseVertices;
    waveMeshFilter.mesh.RecalculateNormals();
    waveMeshFilter.mesh.RecalculateBounds();

    RwaveMeshFilter.mesh.vertices = RbaseVertices;
    RwaveMeshFilter.mesh.RecalculateNormals();
    RwaveMeshFilter.mesh.RecalculateBounds();
}
```

Figure 4.35 GenerateWave function in ReflectWaveGenerator Class

In the GeneratWave() it calculates mesh vertices of both normal wavePlane and reflected wavePlane, and a Raycast is set to check the collision on the right side which is where the reflector placed. If the raycast hit , the calculated reflected wave mesh vertices will apply to the reflected wavePlane ,else the reflected wave plane used the normal wavePlane mesh vertices .In result it creates a reflected wave only when the reflector block the wave. Below is the screenshot of Wave Reflection Simulation (Figure 4.36).

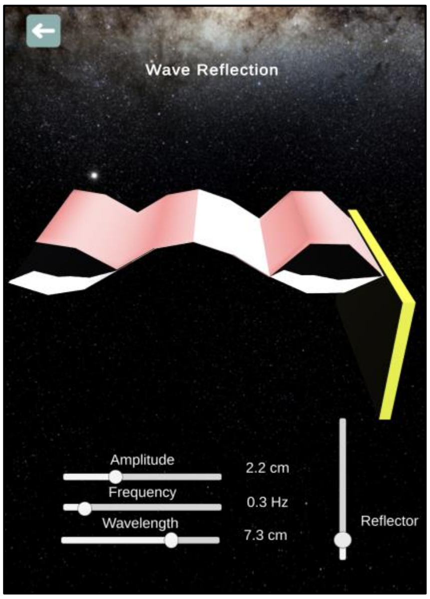


Figure 4.36 Wave Reflection Simulation Screenshot

4.2.4.4 Interference Wave Simulation

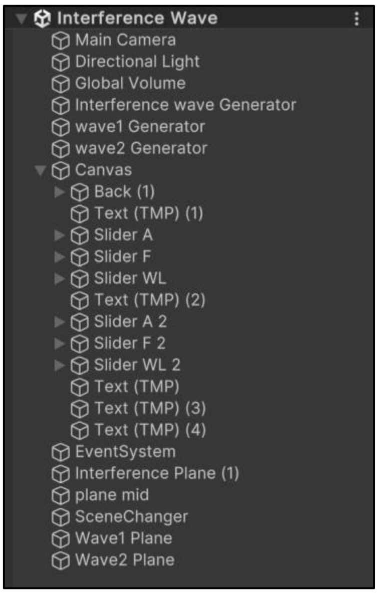


Figure 4.37 Interference Wave Object Hierarchy

In interference wave object hierarchy structure (Figure 4.37), it is also similar with the transverse wave , the only different is that a new wave plane (wave2) is added, and also the interference wave of both wave1 and wave2 are generated. In the component of interference wave generator (Figure 4.38) multiple waves can be added with theirs parameter to form the interference wave.

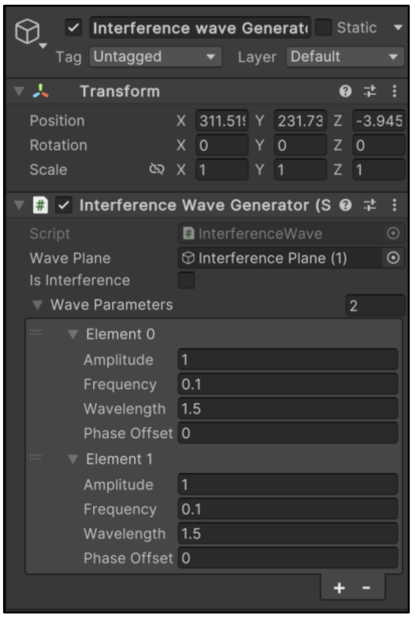


Figure 4.38 Interference wave Generator object

Inside 'Canvas' object contain two set of sliders, one of it is for the wave 1 and another is for wave 2. User can change the parameter by dragging the slider. As most of the code implementation of interference wave simulation is similar to the transverse wave simulation so here only describe the different. Below is the code of GenerateIWave() function in the interference wave simulation script (Figure 4.39)

```
public void GenerateIWave()
{
    for (int i = 0; i < baseVertices.Length; i++)
    {
        Vector3 vertex = baseVertices[i];

        float totalWaveValue = 0f;

        for (int j = 0; j < waveParameters.Length; j++)
        {
            float waveValue = waveParameters[j].amplitude * Mathf.Sin((Time.time * waveParameters[j].frequency + vertex.x / waveParameters[j].wavelength + waveParameters[j].phaseOff
            totalWaveValue += waveValue;
        }

        vertex.y = totalWaveValue;

        baseVertices[i] = vertex;
    }

    waveMeshFilter.mesh.vertices = baseVertices;
    waveMeshFilter.mesh.RecalculateNormals();
    waveMeshFilter.mesh.RecalculateBounds();
}
```

Figure 4.39 GenerateIWave function in InterferenceWaveGenerator Class

As there are multiple waves, the waves are store as an array In the GeneratIWave() when it calculates the mesh vertices, it will also add the value from all of the other's wave parameter. This creates the wave generated become interference wave. Below is the screenshot of Interference Wave Simulation (Figure 4.40).

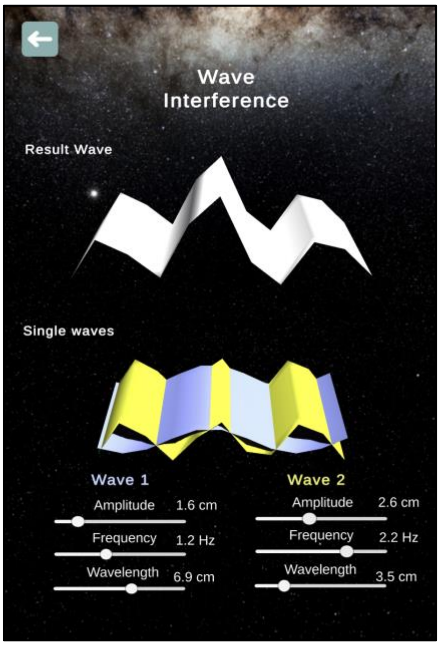


Figure 4.40 Interference Wave Simulation Screenshot

4.2.5 Module 4: AR Playground Module

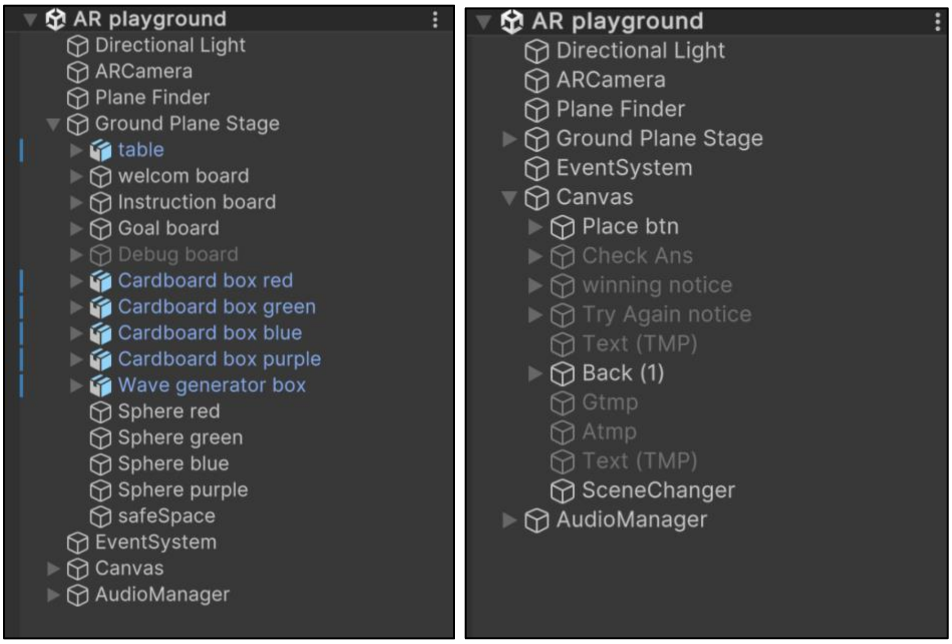


Figure 4.41 AR Playground Object Hierarchy

In AR Playground Scene Vuforia SDK are used, it contains the ‘Plane Finder’ and ‘Ground Plane Stage’ Object (Figure 4.41), ‘Plane Finder’ attached with Vuforia script for detecting the plane surface, and after the surface is found it allows user to anchor the location and place the ‘Ground Plane Stage’ object on the surface. Inside the ‘Ground Plane Stage’ are the puzzle environment designed by author. In this environment four box with a ball inside are create and each ball contain a set of wave parameters, and another box is added collider detection, which help to detect which ball are put inside that box, when a ball is put inside that box the parameter will pass to the wave generator object to generate a wave same as the simulation module. And when multiple ball a put inside the box it will create interference wave , beside the wave create by the ball , there has another pre-set wave , the goal of users is to use the ball to create the wave with same wave pattern to the pre-set wave. Once the user thinks the wave match, he can click on the 'check' button to check the answer is correct or wrong. Below is the screenshot of AR Playground module(Figure 4.42).

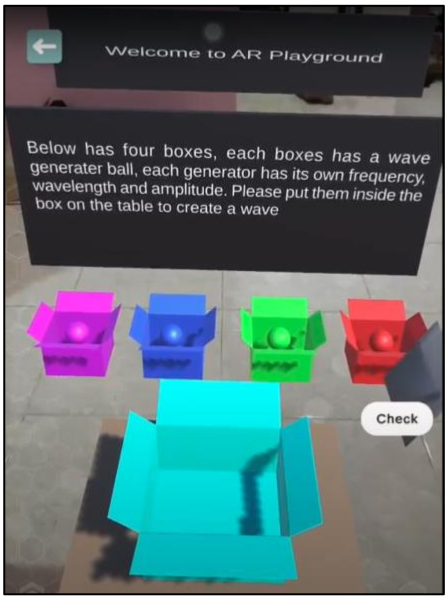
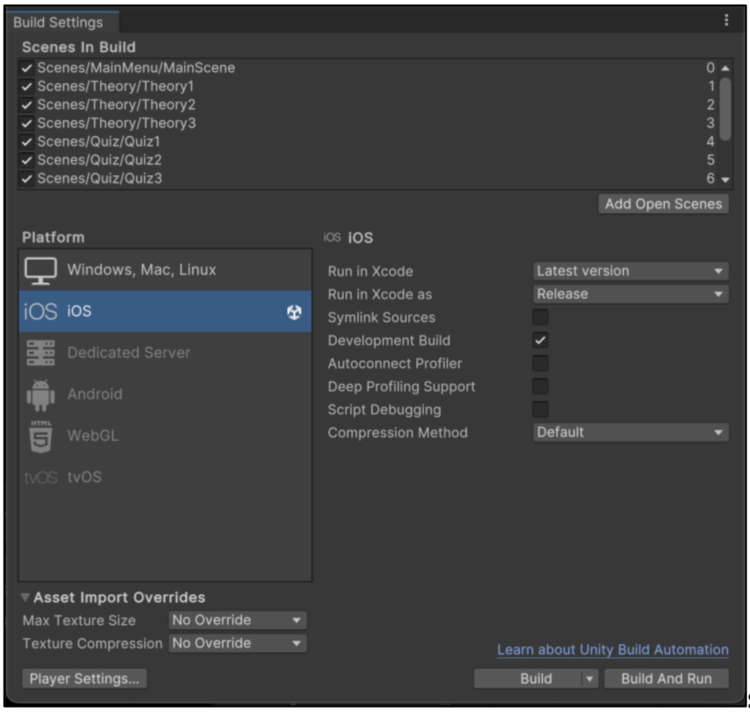


Figure 4.42 AR Playground module Screenshot

4.2.6 Publishing process



s

Figure 4.43 Built setting

As all of the modules are developed, the final step of the development is to make all these scenes to become an application. The first step is to select the application platform and do configuration. This is done by author in the built setting (Figure 4.43). Under player setting(Figure 4.44) author set the bundle identification and other prefer setting. Once all configuration has done author built the unity project to a folder(Figure 4.45).

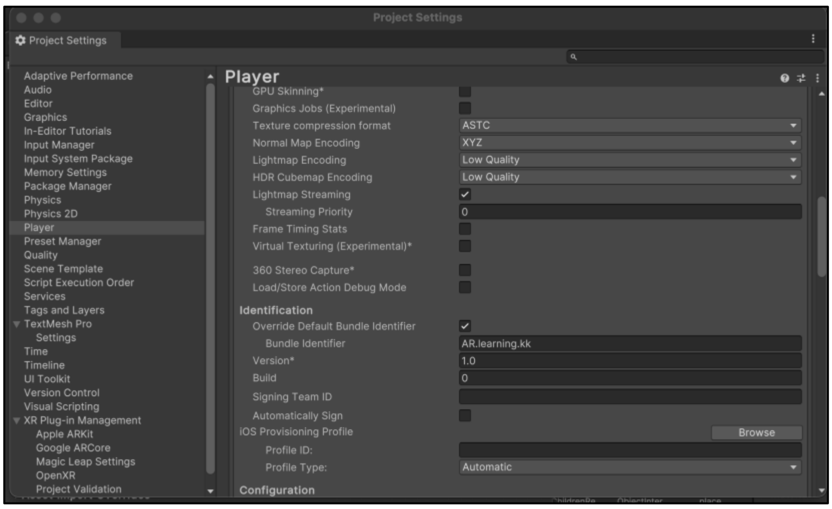


Figure 4.44 Player setting

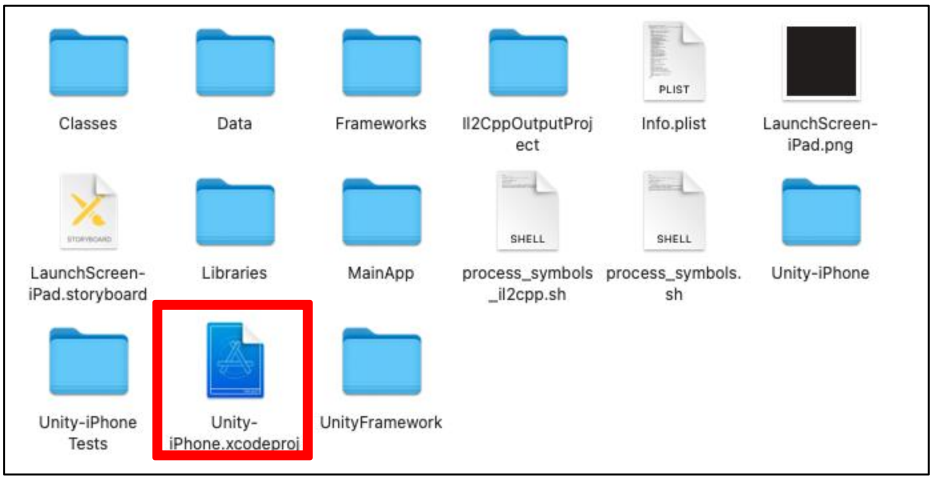


Figure 4.45 Built Folder

In the Built Folder (Figure 4.45) author open the file with .xcodeproj extension and ensure the Bundle Identifier name(Figure 4.46) are same as the bundle identifier set in unity and assigned the team in this page (Figure 4.46)

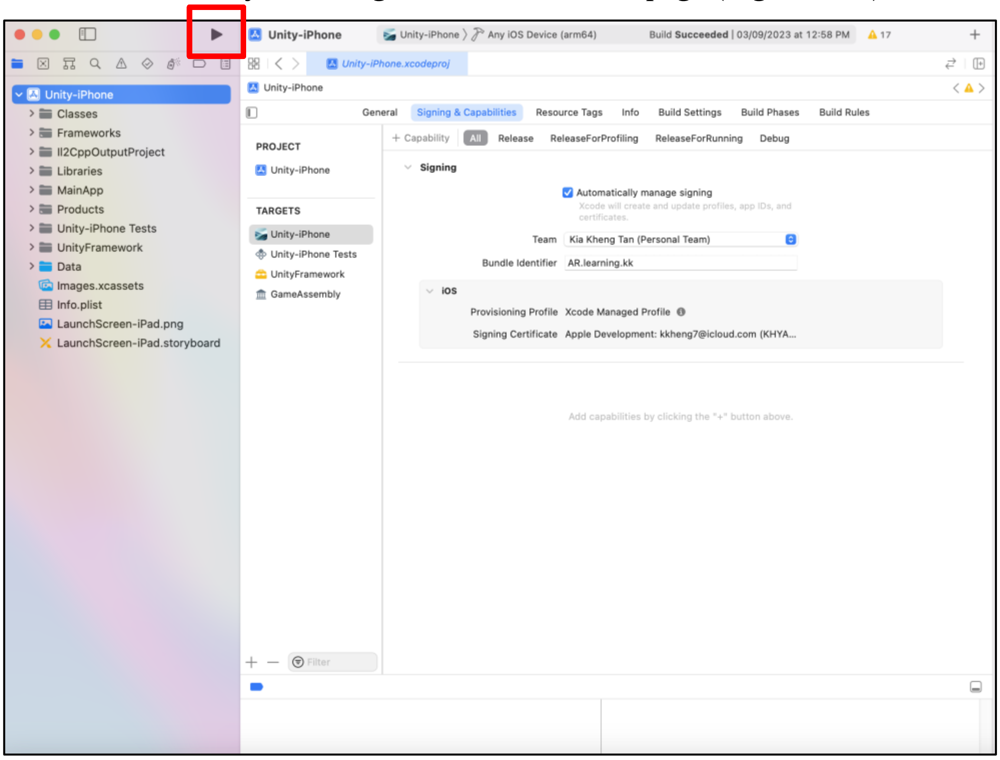


Figure 4.46 Xcode built

Once all the configurations are settled, plug in the app destination device to the development computer click on the play button on the top (Figure 4.46) and wait for the application to be install to the device. And once installed success the publishing process are completed (Figure 4.47).

Figure 4.47 Publish Process Completed

CHAPTER 5

TESTING, RESULT & DISCUSSION

5.1 Overview

In this project the author performs system usability test to evaluate the efficiency and efficacy of the AR aided physics education software. Both System Usability Scale (SUS) and Post-Study System Usability Questionnaire (PSSUQ) are used as these methods of testing as this method is widely used to measure user’s perceived satisfaction and has become the industry standard with references in over 1300 articles and publication.

5.2 Method of Testing

The project's author has created a demonstration video to showcase the functionality and performance of all modules within the application. This video serves as a testing object and is followed by the distribution of two system usability testing questionnaires (SUS and PSSUQ). These questionnaires were sent to individuals aged between 20 and 25 years old to conduct the usability testing. A total of 20 respondents participated in this testing process.

5.2.1 The System Usability Scale (SUS)

The System Usability Scale (SUS) is a reliable "quick and dirty" instrument for measuring usability. It is a ten-item questionnaire with five possible answers for responders, ranging from strongly agree to strongly disagree. It was founded in 1986 by John Brooke and lets people to review a wide range of items and services, including hardware, software, mobile devices, websites, and apps (Affairs, 2013).

5.2.2 Post-Study System Usability Questionnaire (PSSUQ)

The PSSUQ (Post-Study System Usability Questionnaire) is a standardised questionnaire with 16 items. It is commonly used at the end of a research to assess consumers' perceived happiness with a website, programme, system, or product. PSSUQ originated in 1988 as an internal IBM initiative dubbed SUMS (System Usability Metrics) (T, 2021).

5.3 Testing Analysis

SUS

In the SUS questionnaire each question consists of a rating from 1 to 5 which 1 indicate strongly disagree and 5 indicate strongly agree. The final score of the 10 questions is calculated differently, odd questions score is calculated as rating minus 1 , even questions score is calculated as 5 minus rating, after calculating both odd and even question's rating sums up the score and multiply 2.5 to transform the mark from 0-40 to 0-100.The final result will be the average score of all participants.

SUS Score Calculation Step

Step 1. export the result to excel as below (Figure 5.1)

	A	B	C	D	E	F	G	H	I	J	K
1	1) I think th	2) I found the	3) I thought t	4) I think tha	5) I found the	6) I thought t	7) I would im	8) I found the	9) I felt very	10) I needed	Total
2	4	3	4	2	3	3	3	2	3	2	
3	5	1	4	1	5	1	5	1	4	1	
4	1	5	4	3	3	4	1	1	3	3	
5	4	2	4	1	5	2	4	2	5	1	
6	4	3	5	2	4	2	4	3	4	4	
7	4	1	5	1	4	3	4	2	5	1	

Figure 5.1SUS Result in excel

Step 2. Add function (Figure 5.2) to the column of K to calculate the total score from single participant.

```
K2    fx  =SUM(A2,C2,E2,G2,I2)-5*1+ 5*5-SUM(B2,D2,F2,H2,J2)
```

Figure 5.2 Total of SUS score per participant

Step 3. Add function (Figure 5.3) to a cell to calculate the average score from all participants.

```
L2    fx  =SUM(K:K)/20
```

Figure 5.3 calculate average score from all participants

Step 4. Then calculate the final score by multiply 2.5 to the average score ()

```
M2    fx  =L2*2.5
```

Figure 5.4 Calculate Final Score

Step 5. Based on the result, grade is given in table(Table 5.1)

Table 5.1SUS Grade Table

SUS Score	Grade	Adjective Rating
>80.3	A	Excellent
68-80.3	B	Good
68	C	Okay
51-68	D	Poor
<51	F	Awful

PSSUQ

In the PSSUQ questionnaire each question consists of a rating from 1 to 7 which 1 indicate strongly agree and 7 indicate strongly disagree. There are 4 scale in PSSUQ which are the overall, system Usefulness (SYSUSE) , Information Quality (INFOQUAL) and Interface Quality(INTERQUAL). The overall result is calculated by averaging the scores from the 7 points of the scale, (SYSUSE) result are the average score of question 1 to 6, (INFOQUAL) result are the average score of question 7 to 12, (INTERQUAL) result are the average score of question 13 to 15.

PSSUQ Score Calculation Step

Step 1. export the result to excel as below (Figure 5.5)

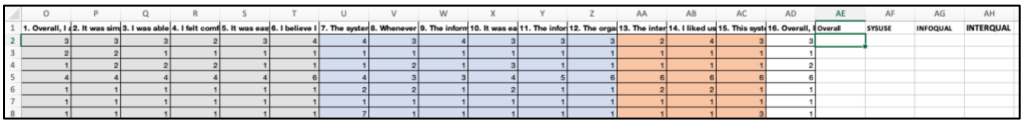


Figure 5.5 PSSUQ Result in excel

Step 2. Add functions as below to calculate score of single participants for overall (Figure 5.6), SYSUSE(Figure 5.7), INFOQUAL(Figure 5.8) and INTERQUAL(Figure 5.9).

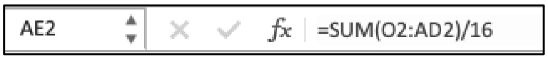


Figure 5.6 Overall score per participant

Figure 5.7 SYSUSE score per participant

Figure 5.8 INFOQUAL score per participant

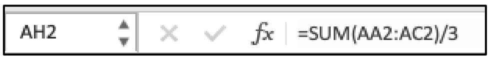


Figure 5.9 INTERQUAL score per participant

Step 3. Add function to a cell to calculate the average score from all participants for overall (Figure 5.10), SYSUSE(Figure 5.11), INFOQUAL(Figure 5.12) and INTERQUAL(Figure 5.13).

Figure 5.10 Average overall score

Figure 5.11 Average SYSUSE score

Figure 5.12 Average INFOQUAL score

Figure 5.13 Average INTERQUAL score

Step 4 Comapre Reference Score(Figure 5.14) by Sauro and Lewis (2016) to the project

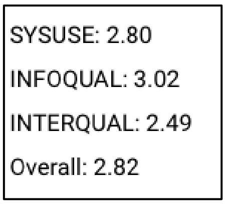


Figure 5.14 Reference Score

5.4 Results and Discussions

A total of 20 individual engaged in the evaluation and testing of this project's usability and user satisfaction by offering useful feedback using the System Usability Scale (SUS) and Post-Study System Usability (PSSUQ) Questionnaire questionnaires. The examination of these scores, as shown in (Table 5.2), provides important data about the project's performance and user response.

Table 5.2 Test Result

Testing Section	Score
SUS	76.375
PSSUQ-SYSUSE	2.153
PSSUQ- INFOQUAL	2.525
PSSUQ- INTERQUAL	2.417
PSSUQ-Overall	2.363

5.4.1 SUS Result and Discussion

According to the System Usability Scale (SUS) grading system, this project's System Usability system (SUS) score is 76.375, which falls within the "B" grade range based on (Table 5.1). This means this project has a high level of usefulness, but there is still potential for development.

5.4.2 PSSUQ Result and Discussion

The PSSUQ (Post-Study System Usability Questionnaire) results give useful insights into several aspects of the project's usability. In context of PSSUQ the lower the score the better the result. The following are the findings:

SYSUSE (System Use):

Project Score: 2.153

Reference Mean: 2.80

The PSSUQ-SYSUSE score indicate the ease of use of the system. The project's score is 2.153, which is much lower than the reference mean of 2.80. Implying that users viewed the system's general ease of use to be highly favourable.

INFOQUAL (Information Quality):

Project Score: 2.525

Reference Mean: 3.02

The PSSUQ-INFOQUAL score is 2.525 which is also lower than the reference mean of 3.02, implying that users rated the system's information quality as adequate, but that there is room for improvement in delivering information that meets or exceeds user expectations.

INTERQUAL (Interface Quality):

Project Score: 2.417

Reference Mean: 2.49

The PSSUQ-INTERQUAL score is 2.417 which is close to the reference mean of 2.49, indicating that users found the system interactions to be relatively well-received. Further improvements to the user experience in terms of interaction quality should be addressed.

PSSUQ-Overall (Overall Satisfaction):

Project Score: 2.363

Reference Mean: 2.82

Although the PSSUQ-Overall score 2.363 indicates that users were satisfied with the project, it is much lower than the reference mean of 2.82. While the project performed well in terms of usability, but as the score is more than 2 show that there are places where changes could be made to improve overall user satisfaction.

5.5 Conclusion of Testing Result

In conclusion, the System Usability Scale (SUS) score of 76.375, which falls within the "B" grade range, shows an acceptable level of usefulness of the project. However, it also implies still untapped potential for future development. The Post-Study System Usability Questionnaire (PSSUQ) offers an in-depth evaluation of usefulness, The project's convenience for use and helpful information quality are highlighted by the positive SYSUSE (System Use) and INFOQUAL (Information Quality) scores. While the INTERQUAL (Interface Quality) score indicates reasonably well-received system interface, there are always chances to improve the user experience. The PSSUQ-Overall score of 2.363, while suggestive of user satisfaction, is performed better than the reference norm of 2.82, indicating areas that are well executed but have the potential to be better.

CHAPTER 6
CONCLUSION

6.1 Overview

In the end all defined project objectives have been effectively met during the duration of the project, which includes the following points:

1. To study the usage of augmented reality and digital media technologies in aiding the learning of Physics.
2. To design and develop the interactive AR aided software for Physics learning using exploratory approach.
3. To design and develop the interactive AR aided software for Physics learning using exploratory approach.

6.2 Research Finding

6.2.1 Objective 1

To study the usage of augmented reality and digital media technologies in aiding the learning of Physics. In this objective, through the finding of similar application, author learnt the recent usage in augmented reality technology such as how marker base is used in learning environment to enhance the learning progress. Besides of finding on similar application, through the research finding author also learn about the learning evolution in physics education which from traditional textbook base to contemporary multimedia base and the learning strategy shift from passive learning to a more dynamic and engaging active learning.

6.2.2 Objective 2

To design and develop the interactive AR aided software for Physics learning using exploratory approach. In this objective, through learning of development tools such as Unity and Vuforia and finding from the similar application, author design a set of modules related to enhance physics learning progress and interactable augmented reality environment in AR Playground module with the fully usage of development tools. This software provides users a place to leaning with exploratory approach and allows them to have enhance visualisation to the physics theory that can ease their learning progress.

6.2.3 Objective 3

To evaluate the effectiveness of the learning software in supporting the learning process. In this objective, author evaluate the software by performing two industry standard system usability testing method which are able evaluate the usability of the software from multiple perspective. From the result of evaluation, the software receives a relatively high level of satisfaction from respondent, and the result also review that the room of improvement can be made from different perspective.

6.3 Problems Faced

6.3.1 Unrealize module -AR object creator (deleted)

There was a proposal at the beginning of the software development process to construct a module called "AR Object Creator." This module was designed to allow users to create 3D objects that could later on be utilised as prefabricated items for interaction within the AR Playground module. However, as work progressed, it became clear that implementing the 3D object creation and editing features would be a more serious and time-consuming effort than expected. Unfortunately, due to time and resource restrictions, it was decided to remove the AR Object Creator module from the project. To compensate for the module's absence, more simulation scenes were integrated into the simulation **module**.

6.3.2 Simulation module development

In the simulation module development, the way to simulate the wave flow are the hardest part for the author , especially on how to make the flow and what object should be used to perform the wave flow , through research and learning online author found that the functionality of mesh filter in Unity provide an easy and effective way to present the wave motion. In result author successful to simulate the wave motion and with sets of parameters allows user to adjust it, provides users to visualise the wave motion in different parameters.

6.3.3 AR Playground module Development

The Vuforia SDK is important in providing augmented reality implementation during the development of the AR Playground module. While the Vuforia documents provided a good foundation for basic implementation, but not sufficient for implement more complex and customise feature. There were not as many examples or thorough instruction for these specific criteria in the documentation. Through multiple experiment with different approaches and several iterations and adjustments in the implementation process, the desired functionality for an interactive augmented reality playground environment was finally achieved.

6.4 Knowledge Gained

6.4.1 The usage of development tools

Throughout this project, the author gained knowledge of the utilization of development tools for applications development. Authors learn how to utilise Unity as an authoring and game development tool to construct applications and deploy them to desired mobile platforms. Besides, author also learns how to configure and customize desirable features in an augmented reality environment using Vuforia SDK as a tool that provides augmented reality implementation.

6.4.2 The process of ADDIE methodology

From involving the whole software development life cycle using from analysis the physics learning environment and similar augmented reality application , design the module for the physics learning software from the result get by analysis phase, development the designed module, implemented the developed software by deploying it to desirable mobile platform and, evaluating by perform system usefulness testing. Through all these processes, author gained better understanding of the ADDIE methodology.

6.4.3 The evaluation of usability of a software

During the project's evaluation phase, the author gained information and abilities relevant to analysing the system's usefulness by using both the System Usability Scale (SUS) and the Post-Study System Usability Questionnaire

(PSSUQ). These evaluation techniques were important to determining the overall efficacy and usability of the developed system.

6.5 Limitation

6.5.1 Device Compatibility and Performance

The reliance on the hardware capabilities of users' devices might be a significant technological limitation. AR applications often require quite a bit of computing power and memory. Users using older or less powerful smartphones or tablets may encounter slowness, crashes, or decreased AR tracking accuracy. This limitation may have an impact on the application's accessibility and user experience.

6.5.2 Environmental Constraints

AR applications, such as this project, rely on real-world conditions to track and position virtual objects. Limitations may occur in surroundings with insufficient light, complex or shiny surfaces, or a lack of identifiable visual components. These variables may affect the application's ability to accurately overlay digital content on the real world, maybe resulting in a poor user experience or even making the application useless in certain situations. For example, the position of the virtual object keeps shifting to other place while user turning or moving their mobile device.

6.5.3 Battery Consumption

AR applications have a high-power consumption, which might be a serious technological limitation. Running the camera, processing AR data, and displaying 3D objects in real-time can quickly drain the battery capacity of a mobile device. This constraint can lead to shorter usage periods, which can be unpleasant for users, particularly if they spend time in lengthy learning or exploring sessions. Optimising the application's power efficiency is important, but reaching the correct balance between AR features and battery usage can be a difficult technological challenge.

6.6 Future Enhancement

For future enhancement , some modules are suggestion as below.

6.6.1 AR LAB module

The AR LAB module should provide AR environment for student to perform lab experiment which lies under their course syllabus. This provides the student a place that allows them to review and experimenting more with ease as most of the experiment only able to conduct once in secondary school in the lab class

6.6.2 AR Multiplayer module

The AR multiplayer module should include games or puzzles that are closely related to physics learning. It should allow multiple users to engage and collaborate in order to solve puzzles and complete the game's objectives

6.6.3 AR Sharing Platform Module

The Sharing Platform module should provide users with the ability to create their own AR puzzles while also allowing them to share these pre-built puzzles online. This sharing feature facilitates collaborative learning and enjoyment among others.

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APPENDICES

A. Questionnaire of System Usability Scale (SUS)

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

B. Post-Study System Usability Questionnaire (PSSUQ)

1. Overall, I am satisfied with how easy it is to use this system.
2. It was simple to use this system.
3. I was able to complete the tasks and scenarios quickly using this system.
4. I felt comfortable using this system.
5. It was easy to learn to use this system.
6. I believe I could become productive quickly using this system.
7. The system gave error messages that clearly told me how to fix problems.
8. Whenever I made a mistake using the system, I could recover easily and quickly.
9. The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.
10. It was easy to find the information I needed.
11. The information was effective in helping me complete the tasks and scenarios.
12. The organization of information on the system screens was clear.
13. The interface of this system was pleasant.
14. I liked using the interface of this system.
15. This system has all the functions and capabilities I expect it to have.

16. Overall, I am satisfied with this system.

C. FYP poster

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Wholly owned by UTAR Education Foundation (Co. No. 578227-M) DU012(A)

INTERACTIVE AUGMENTED REALITY AIDED SOFTWARE FOR PHYSICS EDUCATION USING EXPLORATORY APPROACH

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INTRODUCTION

"Interactive Augmented Reality (AR) is revolutionising education, particularly in physics. This project evaluates the effectiveness and acceptance of AR-aided software in physics education. The goal is to provide students with an interactive and explorative approach to learning physics, promoting immersion and engagement for better understanding.

OBJECTIVE

- To study the usage of augmented reality and digital media technologies in aiding the learning of Physics.
- To design and develop the interactive AR aided software for Physics learning using exploratory approach.
- To evaluate the effectiveness of the learning software in supporting the learning process.

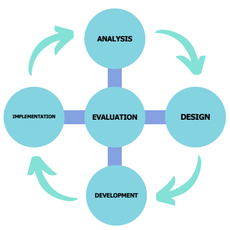
PROMBLEM STATEMENT

- Challenges in visualising physics concepts
- Traditional methods of teaching, Passive Learning
- Challenges of integrating the AR user experience in physics learning

LITERATURE REVIEW

application	audio	BGM	Narator	Simulation	AR	Theory	Text	Video	Image	Animation	Quiz
Big Bang AR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Voyage AR	✓		✓	✓	✓	✓	✓			✓	✓
Spacecraft AR				✓	✓	✓	✓		✓		
Elements 4D				✓	✓	✓	✓			✓	
360ed Electric Circuit AR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

METHODOLOGY - ADDIE MODEL

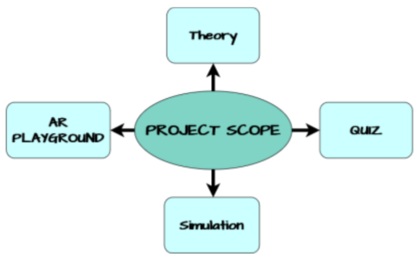


TOOLS

Unity

vuforia

PROJECT SCOPE

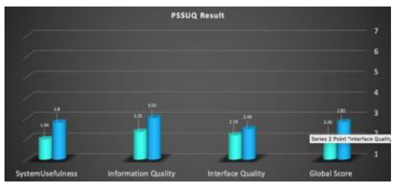


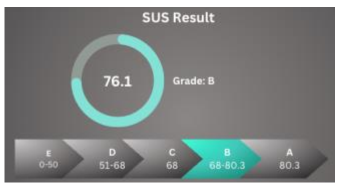
CONTRIBUTION

- **Enhanced participation**: AR-aided physics software encourages student participation through immersive experiences.
- **Improved Understanding**: The software aids in the understanding of unclear physics ideas.
- **Interactive Learning:** Provides an interactive and exploratory approach to fundamental physics topics.

APP SCREENSHOT

RESULT AND DISCUSSION





CONCLUSION

In conclusion, Augmented Reality aided physics educational software offers an attractive way of engaging students, improving comprehension, and encouraging exploration in physics education. The evaluation of the project reveals its effectiveness and favourable student acceptance, establishing AR as a significant tool for modernising physics teaching."