

# AR Moon Stellar Explorer: An Immersive Learning Tool for Year 5 Students

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## Abstract

The integration of Augmented Reality (AR) in educational applications has garnered attention for its potential to engage students more effectively in Science learning. The AR Moon & Stellar Explorer application enhances Year 5 students' understanding of astronomy by providing interactive and immersive experiences centered on the phases of the moon and constellations. This project is particularly significant in addressing the challenges faced by Malaysian students transitioning from learning Science in their native languages to English-based curricula. By offering an AR-based English-learning environment, the application not only bridges this language gap but also fosters a deeper comprehension of complex astronomical phenomena. Developed using the Multimedia Mobile Content Development (MMCD) methodology, the application features interactive elements such as 3D models, AR sessions, and gamified quizzes, creating an engaging and dynamic learning environment that accommodates various learning styles and ensures students grasp both the scientific content and relevant English terminology. Targeting Year 5 students, beta testing revealed a positive satisfaction rate of 84.6%, confirming that the AR Moon & Stellar Explorer application effectively enhances learning outcomes and is well-received by users, despite some challenges with professional terminology.

## 1. Introduction

In recent years, the integration of technology in education has become essential for engaging students from Generation Z and Generation Alpha, who are highly immersed in digital environments. Augmented Reality (AR) has emerged as a powerful tool for enhancing learning experiences, offering interactive and immersive environments that traditional methods often fail to provide. For subjects such as science, where visualizing complex concepts is crucial, AR presents a more effective and engaging way to teach topics like the phases of the moon and constellations. Research has shown that visualizing astronomical phenomena through AR can make difficult concepts more accessible and easier to comprehend [1].

Understanding astronomical phenomena, especially for Year 5 students, can be particularly challenging. Concepts such as the phases of the moon and constellations require clear visualization of celestial movements, which is difficult to achieve using only static diagrams and textbooks. AR technology addresses this issue by allowing students to interact with 3D models of celestial objects, making abstract concepts more tangible and easier to grasp [2]. By integrating AR into the curriculum, students can explore these concepts in a more immersive and dynamic way, significantly improving their understanding of astronomy.

Additionally, Year 5 students in Malaysia typically learn science in their native languages which is Malay, Tamil, or Mandarin. However, the secondary school curriculum is taught in English, which can create a language gap and hinder students' understanding of scientific terminology. This gap can pose challenges for students as they progress in their studies [3]. The AR Moon & Stellar Explorer application aims to bridge this gap by offering an interactive, English-based learning experience that helps students not only grasp scientific concepts but also learn the corresponding English terminology.

The project aims to create an AR (Augmented Reality) educational application for Year 5 students to learn about the moon's phases and constellations. The application will work on Android devices. By using AR technology, it makes learning more fun and interesting compared to regular teaching methods. The goal is to help students understand the material better, spark their interest in science, and create a more interactive learning experience that helps them learn both the content and language skills.

The development of this application follows the Multimedia Mobile Content Development (MMCD) methodology, which ensures the systematic design, development, and testing of multimedia content in mobile applications [4]. MMCD is an approach that focuses on creating interactive mobile learning environments by integrating multimedia elements such as audio, video, animations, and interactive simulations. This methodology is particularly well-suited for developing educational applications that aim to engage students through rich, multimedia experiences. The use of MMCD ensures that the AR Moon & Stellar Explorer application not only meets educational objectives but also provides a user-friendly, interactive platform that enhances the overall learning experience.

The remainder of this paper is organized as follows: Section 2 discusses the domain of study, the technologies used, and the results of the comparative analysis. Section 3 outlines the MMCD methodology employed in the development of this project, including the design and development phases. Section 4 presents the results and discussion, while Section 5 concludes the paper with a summary of progress and future directions.

## 2. Related Work

This section discusses the background of the study, the technology used, and the result of the comparative analysis.

### 2.1 Phases of the Moon and Constellations in Year 5 Science Topic

The Year 5 Science syllabus includes the phases of the Moon and constellations as part of "Earth and Space Science." Students learn to identify the phases of the Moon and recognize constellations like Orion, the Big Dipper, and Cassiopeia, which helps build a foundation in astronomy. The Moon's phases, which follow a cycle of 29.5 days, involve the New Moon, First Quarter, Full Moon, and Last Quarter, caused by the relative positions of the Earth, Moon, and Sun. While students typically use models or diagrams to understand these phases, some may struggle with concepts like the Earth's shadow and the Moon's illumination [5]. Teaching constellations introduces students to patterns in the stars and their cultural and historical significance. Major constellations, like Orion, also play a role in ancient navigation and modern astronomy [6]. Traditional teaching methods, like textbooks, are commonly used for these topics, but integrating technology, such as Augmented Reality (AR), can improve engagement and understanding. AR offers immersive, 3D experiences that help students visualize complex concepts like the Moon's phases and star movement, making these ideas more intuitive and memorable [7].

### 2.2 Augmented Reality in education

Augmented Reality (AR) in education has become a transformative tool, providing interactive and immersive learning experiences that enhance how students engage with and understand educational material. AR overlays digital content onto the real world, creating engaging environments that capture students' attention and increase focus on the lesson at hand [8]. This heightened engagement is particularly beneficial in subjects that students may find challenging or abstract, as the interactive nature of AR helps make difficult topics more accessible and enjoyable [9].

Another important benefit of AR in education is better understanding. Traditional teaching methods often use flat images and text, which may not fully help students understand complicated ideas. AR addresses this limitation by providing 3D visualizations that students can explore and interact with, helping them better understand the relationships and details within the subject matter [10]. Furthermore, AR promotes active learning by enabling students to participate in hands-on experiences, such as conducting virtual experiments or exploring biological structures. This type of interactive learning encourages critical thinking and problem-solving, fostering a deeper and more practical understanding of the material [11].

## 2.3 Comparative Analysis

A comparative analysis was conducted on three astronomy apps: Star Walk 2 [12], Moon Phases AR [13], and Moonme [14] shown in Fig 1. Table 1 shows the results of the comparison based on eight key features: domain, technology, target audience, platform, content, learning module, AR type, operating system, and purchasing model.

AR Moon & Stellar Explorer stands out with its combination of moon phase and constellation learning modules, along with gamified quizzes for better student engagement. Unlike Star Walk 2, which focuses on stargazing with markerless AR, AR Moon & Stellar Explorer uses marker-based AR for a more interactive learning experience. It is designed for Year 5 students in Malaysia, offering content in English while supporting multilingual users. Furthermore, it provides both indoor and outdoor AR experiences, unlike Moon Phases AR and Moonme, which are more limited.

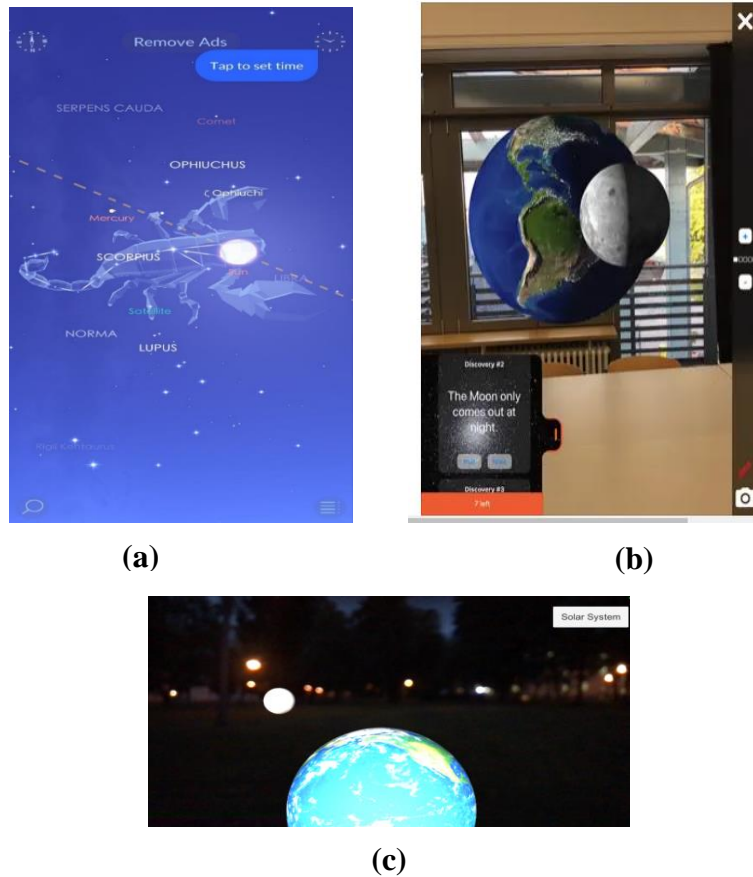


Fig. 1 (a) Star Walk 2 [12]; (b) Moon Phases AR [13]; (c) Moonme [14]

Table 1 Application Comparison

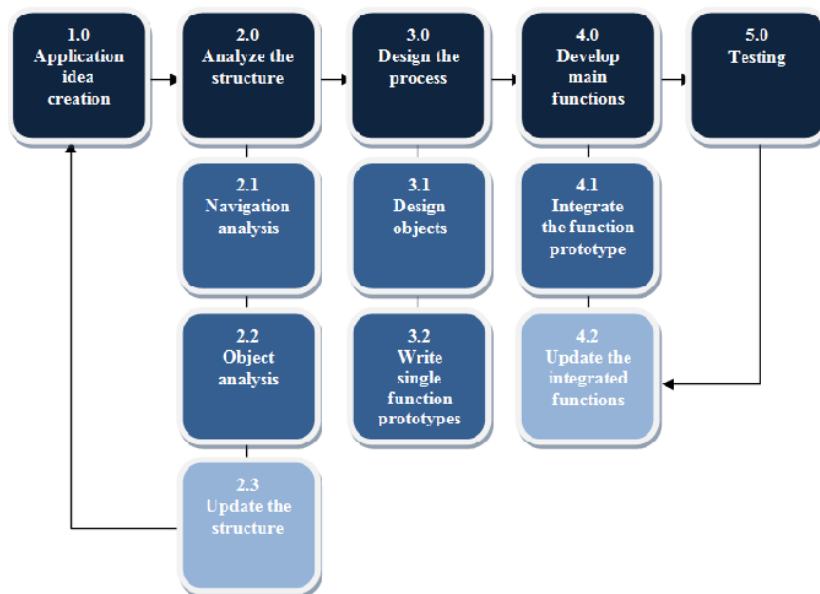
Element / Application	Star Walk 2	Moon Phases AR	Moonme	AR Moon & Stellar Explorer
Domain	Astronomy Education	Astronomy Education	Astronomy Education	Astronomy Education
Module	Night sky and constellations	Moon phases	Moon phases	Moon phases, constellations and Quiz
Technology	AR	AR	AR	AR
Types of AR	Markerless Based	Marker-Based	Marker-Based	Marker-Based
Target User	Amateur stargazers and experienced astronomers	School students	General public, educational use	Year 5 students in Malaysia

**Table 1: cont)**

Setting	Outdoor and Indoor	Indoor and Outdoor	Indoor	Indoor and Outdoor
Purchasing	Free to use	In-app purchasing	In-app purchasing	Free to use
Operating System	Android	iOS	iOS	Android
Supported language	English	English	English	English
Ways to display AR model	Phone camera	Phone camera	Phone camera	Phone camera
Background music	Yes	Yes	No	Yes
Sound effect	Yes	Yes	No	Yes
Quiz module	No	No	No	Yes
AR interactive lessons	Yes	Yes	No	Yes

### 3. Methodology

The AR Moon & Stellar Explorer application has been developed using the Multimedia Mobile Content Development (MMCD) methodology, as depicted in Fig. 2 [4]. The five phases of this methodology are Application Idea Creation Stage, Structure Analysis Stage, Process Design Stage, Main Function Development Stage, and Testing Stage. The Structure Analysis Stage contains three sub-phases: navigation analysis, object analysis, and updating the structure. The Process Design Stage contains two sub-phases: design objects and write single-function prototypes. The Main Function Development Stage involves developing main functions, integrating the function prototype, and updating the integrated functions. Table 7 in Appendix A provides a summary of the output of the five phases of the MMCD methodology.



**Fig. 2 MMCD methodology [4]**

#### 3.1 Application Idea Creation Stage

In this first phase, the initial requirements needed for the development of the AR Moon & Stellar Explorer application are determined. This phase involved reviewing existing applications, interviewing the Subject Matter Expert (SME), and conducting a questionnaire for the target users, Year 5 primary school students, through Google Forms. An interview session was conducted with SME Mr. D. Chandrasegaran, the principal and science teacher, at Sekolah Jenis Kebangsaan Tamil Ladang Juasseh (SJKT). Table 3 shows the user requirement analysis extracted from the SME interview and questionnaire.

**Table 3** *User Requirement Analysis*

Stakeholder Category	Role in Product	User Requirement	Action needed
Subject Matter Expert (Year 5 Science Teacher)	Content Advisor, Subject Alignment	<ul style="list-style-type: none"> <li>• <b>Accuracy and Educational Alignment:</b> The application must accurately represent astronomical phenomena (moon phases, constellations, etc.) and align with the Year 5 science curriculum.</li> <li>• <b>Pedagogical Value:</b> The application should provide engaging and interactive learning experiences that support different learning styles.</li> <li>• <b>Teacher Support:</b> The application should provide resources or tools for teachers, such as lesson plans, assessment materials, or progress tracking features.</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure the educational content is accurate, relevant, and effective in achieving learning objectives.</li> <li>• Enhance student engagement and facilitate effective teaching.</li> </ul>
Students (Year 5)	End-users of the Application	<ul style="list-style-type: none"> <li>• <b>User-Friendliness:</b> The application should be easy to navigate and use with a simple and intuitive interface.</li> <li>• <b>Engaging and Interactive:</b> The AR experience should be captivating and interactive, with features like 3D models, animations, and interactive elements.</li> <li>• <b>Gamification:</b> Incorporate game-like elements (quizzes, rewards, challenges) to motivate and engage students.</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure the application is accessible and enjoyable for all students.</li> <li>• Enhance learning motivation and retention.</li> </ul>

### 3.2 Structure Analysis Stage

The system requirement analysis identifies the necessary features and capabilities that the AR Moon & Stellar Explorer application must have to meet user needs and expectations. This includes a thorough breakdown of both functional and non-functional requirements to ensure the application operates effectively and enhances the learning experience for students. The system flowchart, navigation structure, application module diagram and content structure of each application module are shown in Appendix A to Appendix C.

Functional requirements define the specific behaviors and functions of the application, outlining how it should respond to user actions and interactions. Table 4 provides a detailed description of the key functional requirements for each module.

**Table 4** *Functional Requirements*

Functional Requirement	Module	Description
User interaction support	Main menu module	<ul style="list-style-type: none"> <li>• Users can select a module and navigate using appropriate buttons.</li> </ul>
	Moon module	<ul style="list-style-type: none"> <li>• Users can choose submodules, enter AR sessions, and interact with 3D moon models.</li> </ul>
	Constellation module	<ul style="list-style-type: none"> <li>• Users can choose submodules, enter AR sessions, and interact with 3D constellation models.</li> </ul>

**Table 4** Functional Requirements (cont)

	Quiz module	<ul style="list-style-type: none"> <li>Users can answer questions at three levels and navigate through questions.</li> </ul>
Provide Learning Content	Moon module	<ul style="list-style-type: none"> <li>Users Learning content about moon phases with narration by a 2D character.</li> </ul>
	Constellation module	<ul style="list-style-type: none"> <li>Learning content about constellations with narration by a 2D character</li> </ul>
	Quiz module	<ul style="list-style-type: none"> <li>Assess users' understanding of moon phases and constellations through quizzes.</li> </ul>
Autonomous System Activities	Moon module	<ul style="list-style-type: none"> <li>Display 3D moon phases with animations and descriptions after marker calibration.</li> </ul>
	Constellation module	<ul style="list-style-type: none"> <li>Display 3D constellations with animations and descriptions after marker calibration.</li> </ul>
	Quiz module	<ul style="list-style-type: none"> <li>Evaluate quiz answers, calculate, and display total scores.</li> </ul>

Non-functional requirements define the quality attributes and characteristics that the application must fulfill regarding performance, usability, implementation, and other considerations. Table 5 shows the primary non-functional requirements for the AR Moon & Stellar Explorer application.



**Table 5** Non-functional Requirements

Non-Functional Requirement	Description
Performance	<ul style="list-style-type: none"> <li>The application must be capable of operating completely offline.</li> <li>The application should respond quickly, with a response time of less than 1 second for most Android devices that meet the system requirements.</li> </ul>
Implementation	<ul style="list-style-type: none"> <li>The application should be compatible with Android devices running version 8.1 or above. It must function correctly on these devices.</li> </ul>
Usability	<ul style="list-style-type: none"> <li>Users should be able to access the application anytime and anywhere, provided they have a compatible device.</li> <li>The application should be easy to learn, intuitive to use, and deliver a pleasant overall user experience.</li> </ul>
Legal	<ul style="list-style-type: none"> <li>Users can only view the information displayed in the application and should not be able to modify any content within the app.</li> </ul>
Graphical User Interface Support	<ul style="list-style-type: none"> <li>The application must support all components, including graphics, animations, audio, and text.</li> <li>It should be responsive and display correctly across a variety of screen sizes and resolutions on Android devices.</li> </ul>

### 3.3 Process Design Stage

The third step in the MMCD methodology is the process design stage. The primary objective of this phase is to prepare the application for development. This involves creating a single-function prototype script and designing the necessary objects. Design applications such as Canva are utilized for graphical designs, while Blender is employed to create and generate 3D and 2D models. Unity is used to integrate and combine all required components. The prototype includes essential graphics and object designs that form the AR framework for the proposed application. The next step is to develop the initial script and ensure that all main elements function correctly. This stage is crucial for establishing a solid foundation for the application's functionality. A detailed storyboard is attached in Appendix I. Table 6 shows the button design for the AR Moon & Stellar Explorer application.

**Table 6** Button Design

Button	Function Description
	<ul style="list-style-type: none"> <li>Start button</li> <li>It navigates the user to the main menu</li> </ul>
	<ul style="list-style-type: none"> <li>Labelled button for Moon module</li> <li>It will bring the user to the Moon Module</li> </ul>

**Table 6:** (cont)

	<ul style="list-style-type: none"> <li>• Labelled button for Constellation module</li> <li>• It will bring the user to the Constellation Module</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for Quiz module</li> <li>• It will bring the user to the Quiz Module</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Moon module</li> <li>• It will bring the user to the moon lesson page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Moon module</li> <li>• It will bring the user to the AR moon phases page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Constellation module</li> <li>• It will bring the user to the constellation lesson page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Constellation module</li> <li>• It will bring the user to the constellation type page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for constellation type</li> <li>• It will bring the user to the northern hemisphere constellation type page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for constellation type</li> <li>• It will bring the user to the southern hemisphere constellation type page</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Quiz module</li> <li>• It will bring the user to the beginner level quiz questions</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Quiz module</li> <li>• It will bring the user to the intermediate level quiz questions</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Quiz module</li> <li>• It will bring the user to the advanced level quiz questions</li> </ul>
	<ul style="list-style-type: none"> <li>• Labelled button for submodule of Quiz module</li> <li>• It will bring the user to the intermediate level quiz questions</li> </ul>
	<ul style="list-style-type: none"> <li>• Big Dipper constellation button</li> <li>• It will bring the user to the AR Big Dipper page</li> </ul>

**Table 6:** (cont)

	<ul style="list-style-type: none"> <li>• Orion constellation button</li> <li>• It will bring the user to the AR Orion page</li> </ul>
	<ul style="list-style-type: none"> <li>• Southern Cross constellation button</li> <li>• It will bring the user to the AR Southern Cross page</li> </ul>
	<ul style="list-style-type: none"> <li>• Scorpion constellation button</li> <li>• It will bring the user to the AR Scorpion page</li> </ul>
	<ul style="list-style-type: none"> <li>• Home button</li> <li>• It navigates the user back to the main menu</li> </ul>
	<ul style="list-style-type: none"> <li>• Next button</li> <li>• It navigates the user to the next page</li> </ul>
	<ul style="list-style-type: none"> <li>• Previous button</li> <li>• It navigates the user to the previous page</li> </ul>
	<ul style="list-style-type: none"> <li>• Close button</li> <li>• It allows the user to close the information pop-up</li> </ul>
	<ul style="list-style-type: none"> <li>• Information button</li> <li>• It navigates the user to the information pop-up</li> </ul>
	<ul style="list-style-type: none"> <li>• Audio button</li> <li>• It allows the user to control the audio of the application</li> </ul>

### 3.4 Main Function Development Stage

The implementation of application development is discussed in this section. There are two major stages which are application assets development and integration in Unity with scripting in this section to make the application function with the game assets as well. Table 7 shows the application assets development in AR Moon & Stellar Explorer. Some Interfaces of the built application is shown in Appendix D.

**Table 7** Application Assets Development


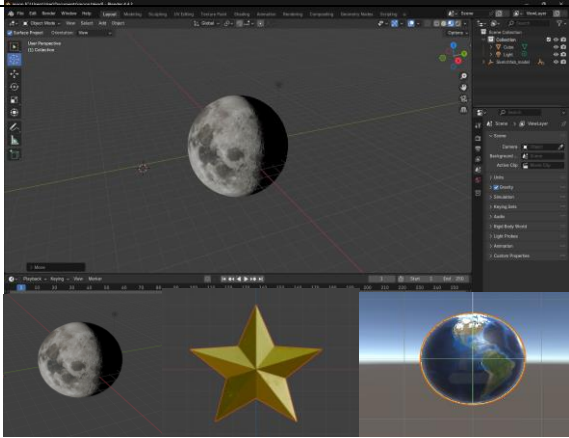
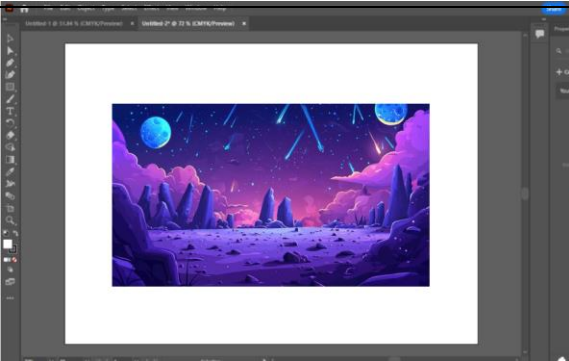
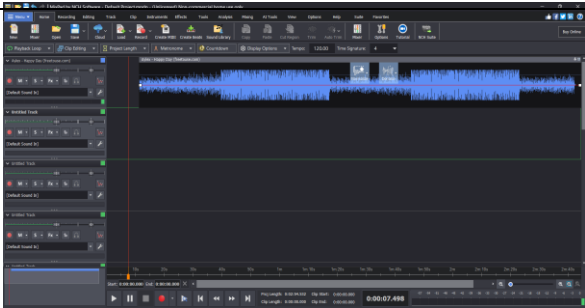
Assets	Development	Description
AR Marker		There are 5 AR Marker for each AR module and here is the example of one of the AR Marker called Moon Phases Marker. The Moon Phases AR Marker designed by using Adobe Illustrator and Canva with a simple shape and colours. It features a cartoon-style moon illustration designed to engage young learners and activate the animation of moon phase transitions in the AR application.
3D Models		The 3D models featured in the AR Moon & Stellar Explorer application primarily depict moon phases and star formations. These models are activated and displayed through the AR module when users scan the respective markers. Three models were developed for the application which are moon, earth and star using blender and unity software.
Graphics		The graphical elements of the application were developed using Canva and Adobe Photoshop. These graphics include backgrounds for modules, such as galaxy or night sky themes; user interface panels for information pop-ups; and iconography elements, including the home icon, back and forward icons, and the exit (X) icon.
Audios		All audio files in the AR Moon & Stellar Explorer application are in MP3 format. The background music was sourced from YouTube and converted using an online converter. Then, GarageBand software was utilized to create the sound effects for interactions within the AR scenes.

Table 7: (cont)

Special Effects		<p>A combination of particle effects has been applied to enhance a usable character known as the "Rocket." These particle effects utilize the particle system provided in Unity 3D, allowing for the creation of simple yet effective visual effects, such as a rocket jet flame.</p>
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Table 8 describes the implementation of essential functions within the application modules, such as Load Scene, Pop Up Panel, Generate Questions and Answers, Drag and Drop, and Exit Function, using scripting.

Table 8 Integration in Unity with Scripting

Functions	Scripts	Description
Load Scene Function	<pre>using UnityEngine; using UnityEngine.SceneManagement; public class SceneManagerScript : MonoBehaviour {     // Load a scene by name     public void LoadScene(string sceneName)     {         SceneManager.LoadScene(sceneName);     }     // Reload the current active scene     public void ReloadCurrentScene()     {         Scene currentScene =         SceneManager.GetActiveScene();         SceneManager.LoadScene(currentScene.name);     }     // Quit the application     public void QuitGame()     {         Debug.Log("Quitting the game...");         Application.Quit();     } }</pre>	<p>The SceneManagerScript.cs script manages scene loading and application quitting using Unity's built-in SceneManager and Application classes directly, rather than relying on public GameObject array variables. It exposes three public functions: LoadScene(string sceneName), ReloadCurrentScene(), and <b>QuitGame()</b>. These functions directly call the corresponding SceneManager or Application methods to perform their respective actions without using any for-loops.</p>
Pop Up Panel	<pre>using UnityEngine; using UnityEngine.UI; using System; using System.Collections; public class MoonPopUpUI : MonoBehaviour {     public GameObject panel; // Assign the Panel     public Text nameText; // Assign the Text (or     // TMP_Text)     public void ShowName(string name, Action     onComplete)     {         if (panel == null    nameText == null)         {             Debug.LogError("MoonPopUpUI: Panel or</pre>	<p>The MoonPopUpUI.cs script controls a pop-up UI with a name display. It has public variables for the panel and name text. The <b>ShowName</b> function displays the pop-up with a given name and starts a coroutine. The <b>CloseAfterDelay</b> coroutine automatically closes the pop-up after 2 seconds and executes an optional action. The script includes error handling for unassigned panel or name text.</p>

Table 9: (cont)

	<pre> return; } Debug.Log("MoonPopUpUI: Showing pop-up for " + name); panel.SetActive(true); nameText.text = name; StartCoroutine(CloseAfterDelay(onComplete)); } private IEnumerator CloseAfterDelay(Action onComplete) { yield return new WaitForSeconds(2f); panel.SetActive(false); onComplete?.Invoke(); } } </pre>	
Generate Questions and Answers	<pre> void generateQuestion() { if (QnA.Count &gt; 0) { currentQuestion = Random.Range(0, QnA.Count); QuestionTxt.text = QnA[currentQuestion].Question; SetAnswers(); questionTimer.SetDuration(10).Begin();  int currentQuestionNumber = totalQuestions - QnA.Count + 1; QuestionCounterText.text = currentQuestionNumber + "/" + totalQuestions; } else { GameOver(); } }  void SetAnswers() { ResetButtonColors(); for (int i = 0; i &lt; options.Length; i++) { options[i].GetComponent&lt;Image&gt;().sprite = QnA[currentQuestion].Answers[i];  options[i].GetComponent&lt;AnswerScriptIntermediat e&gt;().isCorrect = (QnA[currentQuestion].CorrectAnswer == i);  options[i].GetComponent&lt;Button&gt;().interactable = </pre>	<p>The QuizManager.cs script has a <b>generateQuestion()</b> function that selects a random question from the QnA list. It displays the question text, calls <b>SetAnswers()</b>, starts a 10-second <b>QuestionTimer</b>, and updates the question counter. If no questions remain, it calls <b>GameOver()</b>. The <b>SetAnswers()</b> function resets button colors, then iterates through the <b>options</b> array to set the answer images and the <b>isCorrect</b> property of each answer button based on the <b>currentQuestion</b>. It also ensures all answer buttons are interactable.</p>

### 3.5 Testing Stage

In this section, the implementation of application assets and scripting integration is discussed. Alpha testing is performed to verify whether the functionality of the AR Moon & Stellar Explorer is as expected. Corrective

measures are taken if any issues are identified. In addition, beta testing is also conducted with the target user by using Technology Acceptance Model (TAM) [16], which measure user acceptance towards the application based on the constructs verified. TAM includes the survey items such as perceived usefulness, perceived ease of use, user satisfaction, and attribute of usability [17]. Table 8 shows the results of alpha testing while the results of beta testing are discussed in Section 4.

**Table 9** Results of alpha testing

Test	Expected Result	Actual Result	Corrective Action
Start Button	Navigates to Module Selection Scene (Home Page)	Works well as expected.	Not needed.
Moon Module Button	Navigates to Moon Module Scene.	Works well as expected.	Not needed.
Constellation Module Button	Navigates to Constellation Scene.	Works well as expected.	Not needed.
Quiz Module Button	Navigates to Quiz Module Scene.	Works well as expected.	Not needed.
Moon Lesson Button	Navigates to Moon Lesson Scene.	Works well as expected.	Not needed.
AR Moon Phases Button	Navigates to AR Moon Phases Scene	Works well as expected.	Not needed.
Constellation Lesson Button	Navigates to Constellation Lesson Scene.	Works well as expected.	Not needed.
AR Constellation Button	Navigates to Constellation Scene	Works well as expected.	Not needed.
Home Button	Navigates to Module Selection Scene (Home Page)	Works well as expected.	Not needed.
Back Button	It navigates to the previous scene.	Works well as expected.	Not needed.
Exit Button	Display the Exit Panel.	Works well as expected.	Not needed.
Answer Option Buttons	Show the correct or wrong feedback.	While being clicked many times, the score continues to increase.	Add a cover to avoid double-clicking the answer option.
AR calibration	The calibration changes for the AR marker are to display the 3D model of moon phases and constellation.	Works well as expected.	Not need.
AR interaction	The interaction such as rotate, click, drag and drop are functional.	Works well as expected.	Not need.

#### 4. Results and Discussion

For beta testing, evaluation was conducted by involving target users by using Technology Acceptance Model (TAM). The questionnaire items were measured by using a “yes”, “no” or “not sure” to scale the questions asked. The questions according to TAM are listed in Table 10.

**Table 10** Technology Acceptance Model (TAM) for evaluating application quality

Constructs	Evaluation variables	Measured Items
Perceived of usefulness (PU)	Learning Outcome Acquisition	PU1: I am able to recognize the different phases of the moon and identify constellations after using the application. PU2: I can understand how the moon phases transition from one to another through the AR module. PU3: I am able to pronounce and read the names of

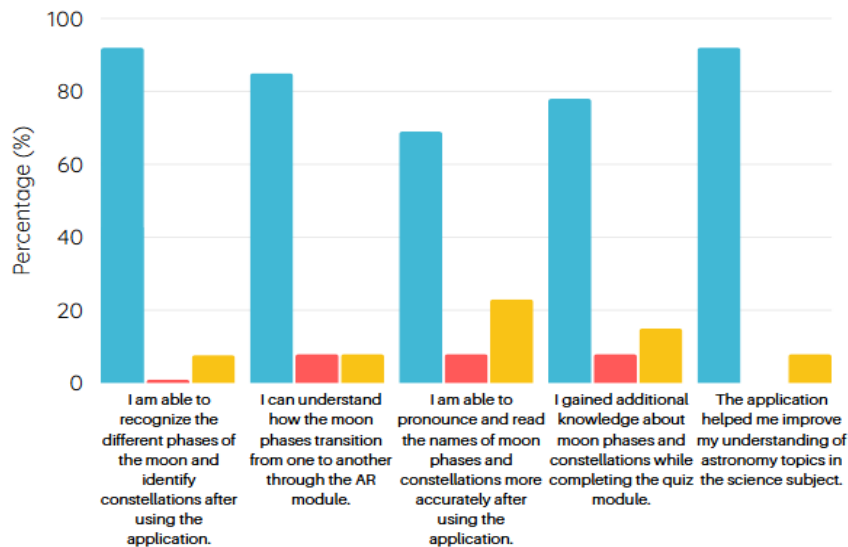
moon phases and constellations more accurately after using the application.  
 PU4: I gained additional knowledge about moon phases and constellations while completing the quiz module.

**Table 10:** (cont)

Perceived ease of use (PEOU)	User acceptance level (Usability)	PEOU1: I find the 3D models and visual elements in the application attractive and suitable for learning. PEOU2: I enjoy using the application because it is easy to navigate and understand. PEOU3: I would recommend this application to my friends or classmates. PEOU4: I feel motivated to learn science through this interactive learning method. PEOU5: The overall experience of using the application is enjoyable and engaging.
The attribute of usability (AU)	Functionality	AU1: The buttons and navigation controls are easy to understand and use.

A set of Google Form questionnaires was prepared for the target users to facilitate data analysis, as the generated data can be represented in figures and charts, minimizing human error during calculations. The questionnaire consists of 16 questions divided into four sections: learning outcome acquisition, user acceptance level, overall performance and functionality, and demographic information. Target users were required to provide feedback via the questionnaire after testing the AR Moon & Stellar Explorer application. Additionally, user testing was conducted with a Subject Matter Expert (SME), Mr. D. Chandrasegaran, a science teacher from SJKT Ladang Juasseh in Kuala Pilah, Negeri Sembilan, whose comments were recorded. A total of 13 Year 5 students participated in the beta testing, comprising 6 males and 7 females. The results of the testing are discussed in the following section, which covers the results and discussion.

**Perceived of usefulness (PU): Learning Outcome Acquisition**



**Fig. 3** Analysis of learning outcome acquisition

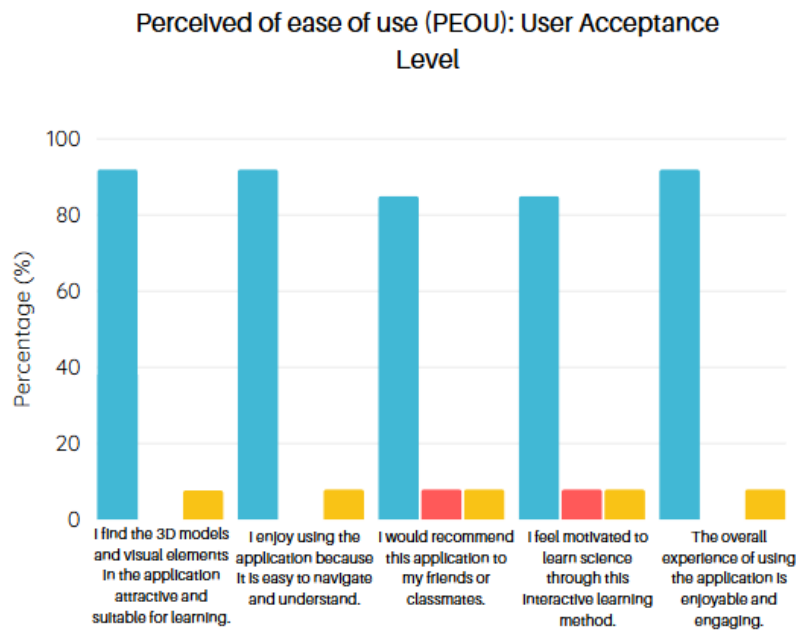


Fig. 4 Analysis of user acceptance level

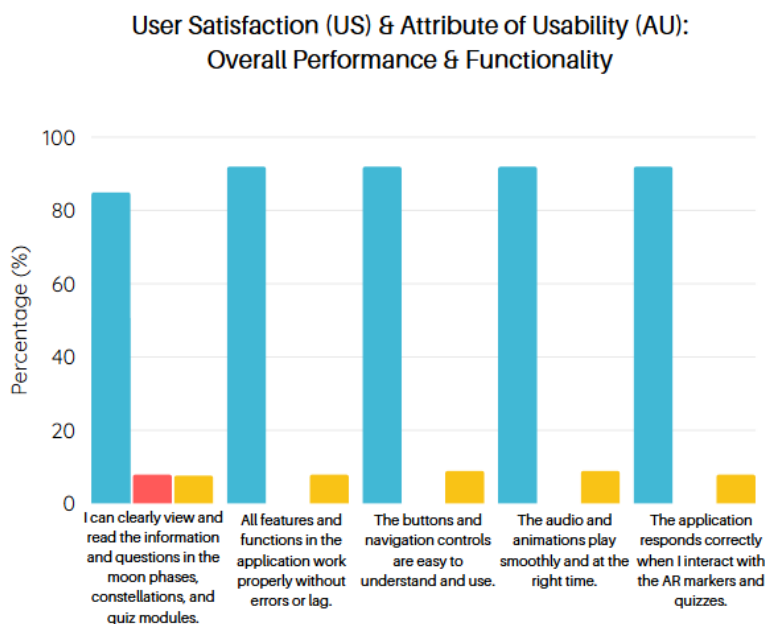


Fig. 5 Analysis of overall performance and functionality

Based on the results presented in Figures 3, 4, and 5, an average of 84.6% of respondents expressed satisfaction with the learning outcomes, graphics, overall performance, and functionality provided by the AR Moon & Stellar Explorer application. Despite this high level of satisfaction, some respondents provided negative feedback, indicating uncertainty in reading, speaking, and understanding the information within the application. This may be attributed to the challenges posed by professional terminology related to moon phases and constellations, which may be unfamiliar to students at this age. To address this, simplifying terminology and incorporating more graphical learning elements could be beneficial in future iterations. Overall, the number of positive responses significantly outweighs the negative, suggesting that the project's objective of creating an

interactive and motivating AR learning application for the topics of moon phases and constellations has been achieved.

The Subject Matter Expert (SME) provided positive feedback on the design, reliable content, and appearance of the AR Moon & Stellar Explorer application. He agreed that the application successfully promotes interactive and motivating learning through AR and noted that the quiz module offers students a relaxing activity during their learning time. However, he suggested that the application could benefit from additional graphical elements, such as pictures and videos, to replace text descriptions in the lesson module, as unfamiliar terms or sentences may confuse students.

## 5. Conclusion

In summary, this project has achieved significant progress in developing the AR Moon & Stellar Explorer application, successfully laying the foundation for an engaging and interactive learning tool designed to enhance Year 5 students' understanding of moon phases and constellations, addressing the challenges of transitioning to English-based science curricula by providing an immersive environment; the completion of the storyboard, system analysis, and the functional Moon Module demonstrates the application's feasibility, however, future work should prioritize the integration of more graphical elements like pictures and videos to supplement text descriptions, refine the application based on user feedback to ensure intuitiveness and engagement, and expand the content to include additional astronomical concepts and interactive features, ultimately aiming to fully realize its potential as an innovative educational tool that transforms how young learners explore and comprehend astronomy, fostering a deeper appreciation for the moon, stars, and the universe beyond.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

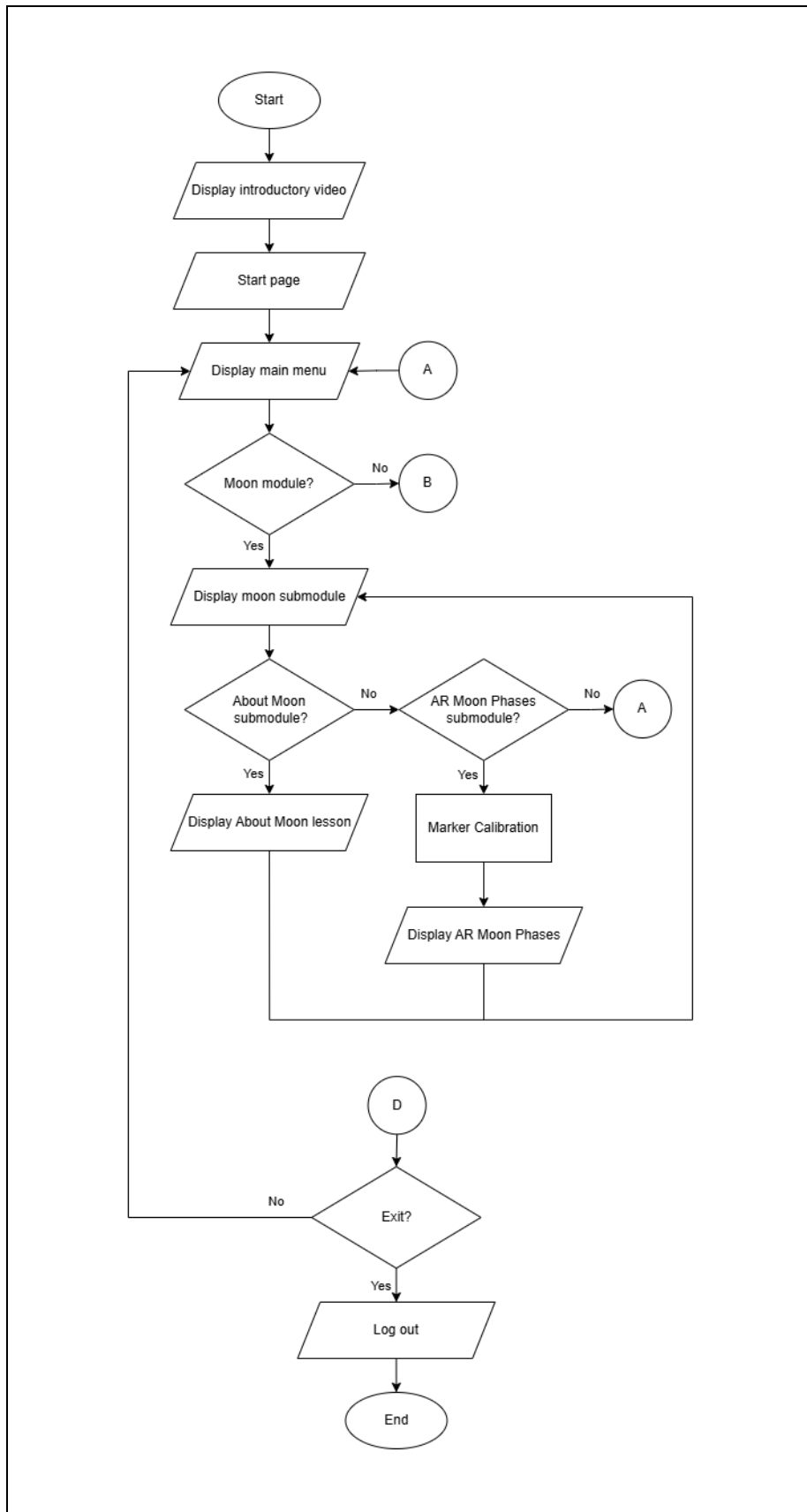
The authors confirm contribution to the paper as follows: **study conception and design:** Yugeswary Chandran, Rahayu A Hamid; **data collection:** Yugeswary Chandran, Rahayu A Hamid; **analysis and interpretation of results:** Yugeswary Chandran, Rahayu A Hamid; **draft manuscript preparation:** Yugeswary Chandran, Rahayu A Hamid. All authors reviewed the results and approved the final version of the manuscript.

## References

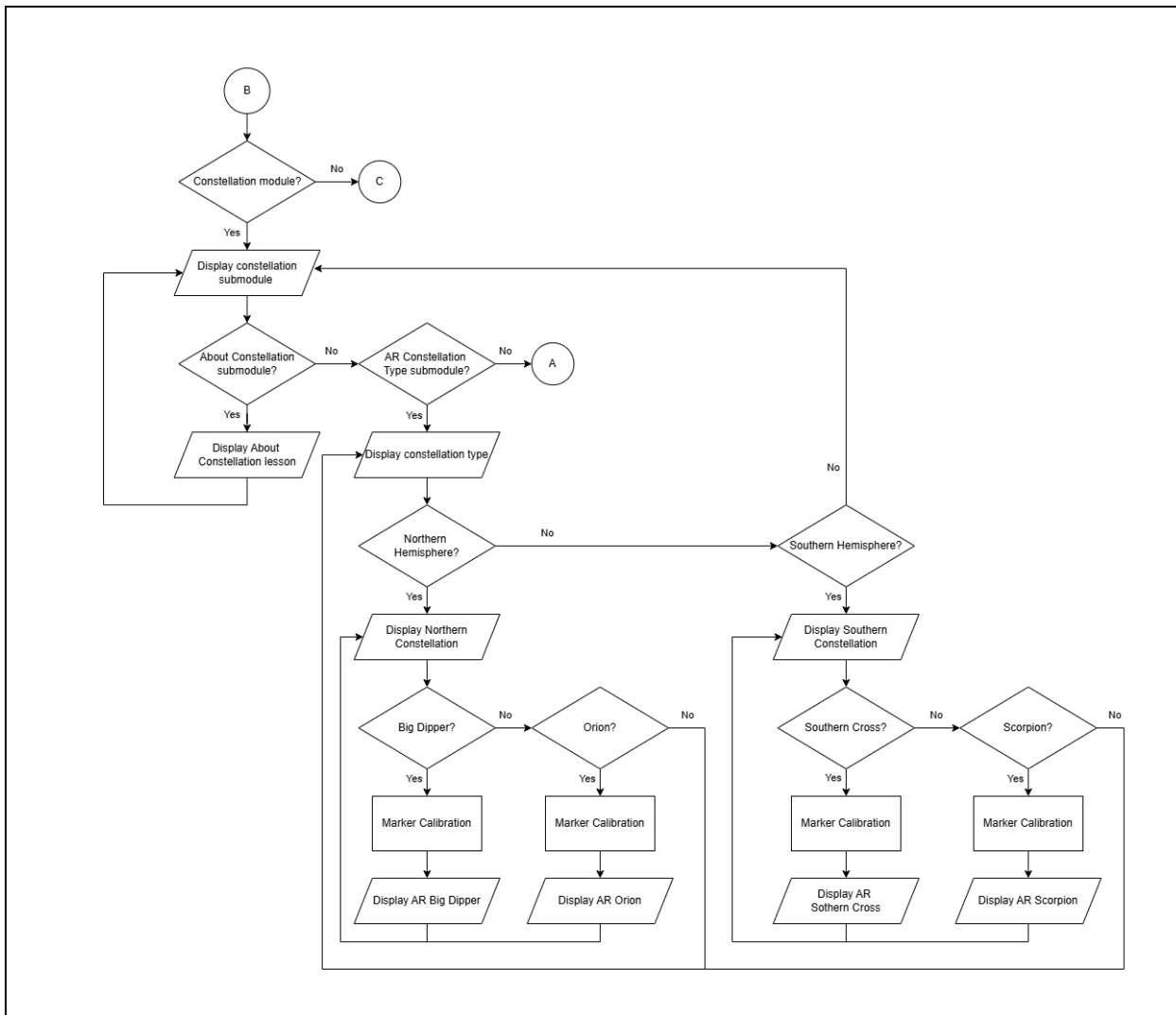
- [1] Ahmad, S., & Othman, M. (2020). The role of augmented reality in science education: Enhancing student engagement in learning astronomy concepts. *International Journal of Educational Technology*, 12(2), 155-170.
- [2] Dinther, M., et al. (2021). The effectiveness of augmented reality in teaching difficult science concepts: A case study on astronomy. *Journal of Educational Technology*, 16(4), 310-320.
- [3] Suh, S., & Lee, M. (2021). Addressing the challenge of language barriers in science education with AR-based applications. *Educational Technology Research and Development*, 69(2), 377-389.
- [4] Nasaruddin Saifudin, W. S., Salam, S., & Abdullah, M. H. L. (2012). Multimedia Mobile Content Development Framework and Methodology for Developing M-Learning Applications. *Journal of Technical Education and Training*, 4(2), 14-22. ISSN 2229-8932. Retrieved from [www.ftmk.utm.edu.my/wansazli/mnations](http://www.ftmk.utm.edu.my/wansazli/mnations)
- [5] Slater, T. F., & Gelderman, R. (2017). Addressing students' misconceptions about eclipses. *The Physics Teacher*, 55(5), 314-315.
- [6] Haynes, A., and J. Roberts, "Integrating Indigenous Astronomy into Modern Curricula," *Cultural Astronomy Journal*, vol. 15, no. 2, pp. 45-56, 2019.
- [7] Yusof, A. S., Ajmain, M. T., Rahim, S. A., & Abuhassna, H. (2022). Implementation of augmented reality (AR) in Malaysian education system. *International Journal of Academic Research in Progressive Education and Development*, 11(3), 1207-1216.

- [8] Adamska, I. (2023). 9 benefits of augmented reality in education. Retrieved from: <https://nsflow.com/blog/9-benefits-of-augmented-reality-in-education>
- [9] Shankar, A. U., Nandi, V. T., Rahman, M., Mishra, A., & Bajaj, K. K. (2023). Impact of virtual reality (VR) and augmented reality (AR) in education. *Tuijin Jishu/Journal of Propulsion Technology*, 44(4), 1310-1318.
- [10] Connell, L. (2012). The impact of traditional vs. interactive instruction on student comprehension (Master's thesis). St. John Fisher University.
- [11] Singh, G., & Ahmad, F. (2024). An interactive augmented reality framework to enhance the user experience and operational skills in electronics laboratories. *Smart Learning Environments*, 11(1), 1-23. <https://doi.org/10.1186/s40561-023-00287-1>
- [12] Vito Technology. (2015), *Star Walk 2 Ads+ Sky Map View*. Retrieved from Google Play: <https://play.google.com/store/apps/details?id=com.vitotechnology.StarWalk2Free&hl=en>
- [13] AR by Teachers a LP. (2018). *Moon Phases AR*. Retrieved from Apple App Store: <https://apps.apple.com/us/app/moon-phases-ar/id1437094226>
- [14] Login, D. (2022). Moonme: Moon phases and lunar calendar. Google Play. Retrieved November 23, 2024, from <https://play.google.com/store/apps/details?id=com.logindai.Moonme&hl=en>

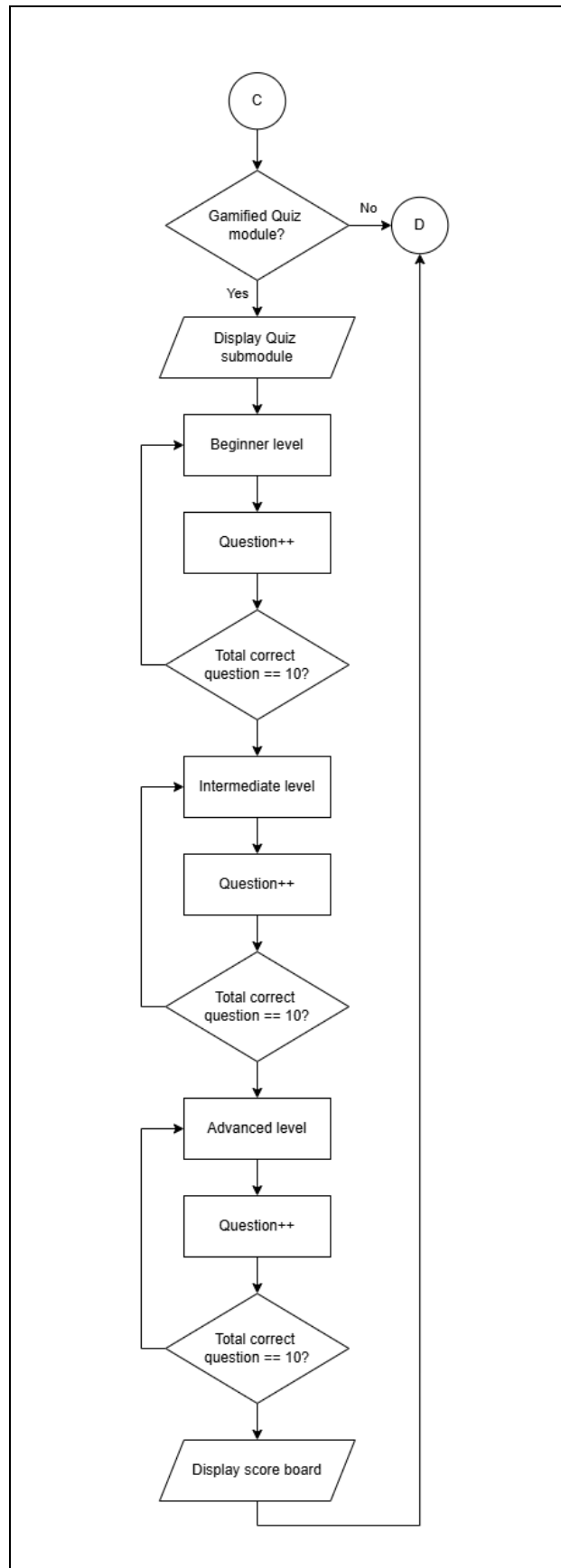
**Appendix A: Main flowchart with Moon module**






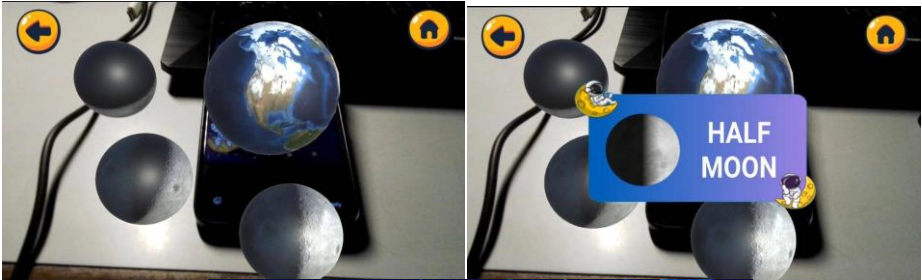

### Appendix B: Flowchart of Constellation module



## Appendix C: Flowchart of Quiz module



### Appendix D: Interface of built application

Module	Interface
Main Menu	
Home	
Moon Module	 
Constellation Module	
Quiz Module	