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The Development of Augmented Reality Mobile Application: BrainARnatomy

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Abstract: The brain is a powerful organ that manages thinking, memories, emotions, sensation, motor skills, vision, respiration, temperature, and hunger. Like other organs, the brain has various components that are each in charge of a certain function. The intricate folds and grooves enable different sections to connect and facilitate human behavior. Educating children about brain function can boost their confidence, although practical implementation remains pending. This proposal aims to create an augmented reality (AR) mobile app, BrainARnatomy, targeting 10-year-old children. Utilizing the Multimedia Mobile Content Development (MMCD) approach, this app will raise awareness about the brain, foster a growth mindset, and provide information about its different parts. This application is expected to be useful for providing background knowledge on the brain, growth mindset, and various parts of the brain.

Keywords: Augmented Reality, Mobile Learning Application, Brain anatomy

1. Introduction

The brain, a crucial organ in humans, functions as the body's control center. An interactive experience called Augmented reality (AR), a blend of computer-generated content and the real world, has gained popularity beyond gaming, with a growing interest in using AR for educational purposes. In education, the integration of science and AR technology facilitates an enhanced understanding of complex concepts, particularly in human anatomy. To address this, "BrainARnatomy," an AR application, has been developed to introduce 10-year-old children to the different parts of the brain. This combination of augmented reality and brain anatomy holds immense importance in developing more effective educational approaches, specifically targeting children's understanding of anatomy. By utilizing AR, we aim to create an engaging and informative learning experience, revolutionizing the way anatomy is taught.

The objectives of this study are to design the BrainARnatomy mobile AR application using an Augmented Reality (AR) and trivia gamification approach, to develop the BrainARnatomy application on the Android platform by using Unity software, and to test the developed application's functionality and users' acceptance, children who are 10 years old. Hence, the contents and the language used in this application will be simple and easy to understand for the targeted users. English will be used as the

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main and only delivery language. The use of English aims to help young users become accustomed to the globally used language while they are still young, so that they are better prepared when they enter secondary school.

The application comprises two modules: Brain in AR and Test Your Brain. The AR-based Brain in AR module features six parts: parietal lobe, frontal lobe, occipital lobe, cerebellum, temporal lobe, and spinal cord. Each part includes graphics and a simple explanation of its functions. An AR button allows users to activate the AR camera, which displays a 3D model of the brain components upon recognizing an image like a flash card. Each part's content includes information on its location, important functions, and suggestions for improvement through healthy food choices. The application also includes an exercise module that complements the concepts presented in the Test Your Brain module. Puan Azura binti Ghazali, a science teacher with 15 years of teaching experience at SK Section 18 Shah Alam, Selangor, serves as the subject matter expert (SME) for this project.

In this project, Canva is used for image editing, Blender is used to create 3D models of the brain, and Unity is used to develop the whole AR application and interactivity. Alongside informative explanations, challenging quizzes on brain anatomy and function enhance the app's appeal. These applications can be especially useful for educators and parents who are intimidated by the prospect of explaining a subject as complex as the brain.

The rest of the paper is arranged as follows: Section 2 covers the domain of study, the technology used, and the result of the comparative analysis. Section 3 describes the Multimedia Mobile Content Development (MMCD) methodology that is chosen to apply in this project, as well as the output of the analysis and design phases of this project. Furthermore, Section 4 stated the conclusion of the current progress.

2. Related Work

In this section, the study domain, the technology used, and the result of the comparative analysis are discussed.

2.1 Brain anatomy

The brain, enclosed within the skull, consists of extensive nerve tissue and plays a vital role in numerous bodily systems [1]. It receives sensory input from sight, smell, hearing, touch, and taste simultaneously, connecting with all the body's nerves, including those in the spinal cord [2]. When humans encounter something remarkable or painful, our bodies transmit information to the brain, enabling us to perceive our surroundings and determine appropriate responses. Additionally, the brain utilizes these nerves to communicate with our muscles, initiating movement, speech, or stretching in response to its impulses. Contrary to a mere cluster of cells, the brain's anatomy is intricate and highly detailed, reflecting its complexity within the confines of our skull.

2.1.1 Technologies for brain anatomy learning

In this modern day, Technologies for brain anatomy learning encompass a wide range of innovative tools such as Augmented Reality (AR), Virtual Reality (VR), and Magnetic Resonance Imaging (MRI). These technologies enhance the educational experience by providing interactive and immersive platforms for students and educators to explore and understand the complexities of brain anatomy. [3]. AR utilizes markers and overlays to overlay digital content onto real-world views, while VR creates simulated environments for immersive learning. MRI scans provide detailed structural information, enabling the creation of accurate virtual brain models. Together, these technologies revolutionize brain anatomy learning, making it engage, accessible, and informative.

2.1.2 Brain anatomy learning for children.

Children learn about brain anatomy to understand how the brain works and to help them comprehend how the brain functions. Children will be more receptive to various methods and education if they are taught about the brain's functioning [4]. They learn more about themselves and the relationship between their thoughts, feelings, and brains as a result. Children who study the brain also develop better memory, attentiveness, and problem-solving abilities. Demonstrating how the brain affects our emotions and behaviour, it teaches kids to be kind and empathetic to others. Children gain an interest in learning about the structure of the brain through engaging activities including models, drawings, and simple explanations. Their interest in learning more about the brain as they get older may increase because of this information.

2.2 Interactive technology

Touchscreens, motion sensors, virtual reality (VR), augmented reality (AR), and gesture recognition systems are just a few examples of interactive technology's many manifestations. Technologies allow users to engage with digital content through interactivity, user control, and responsiveness. Users can respond to stimuli, manipulate the content, and receive feedback based on their actions. This interactive nature of technologies fosters active participation, exploration, and a sense of agency, enhancing overall engagement and immersion in the digital experience. In education, interactive digital learning with game-based learning, VR, and AR technologies is gaining popularity. The events of 2020 highlighted the need to incorporate interactive elements into hybrid homeschooling and online education.[5]. Interactive learning actively involves students, moving away from passive lectures and readings. This approach increases engagement, expands participation, and provides more assessment options. Amidst the pandemic-driven shift to online learning, teachers aim to recreate the traditional classroom environment as closely as possible, recognizing its importance.

2.2.1 Mobile application

Software, or a collection of software programs, known as mobile applications, run on mobile phones and perform tasks for the user [6]. Mobile applications are a brand-new and quickly expanding field of information and communication technology. Most mobile phones, including entry-level and affordable phones, can download and run mobile applications that are simple, user-friendly, affordable, and easy to use. Due to its extensive functionality, the mobile application can be used for a variety of purposes, including calling, texting, browsing, messaging, social network communication, audio, video, and gaming.

2.3 Augmented reality approach

There are two major kinds of augmented reality. The first is known as marker-based AR, and the second is known as marker-less AR. While marker-less AR is being used without markers, marker less AR requires markers as a trigger. Each has specific goals, requirements, and application use cases. The marker-based strategy is used to create the intended application.

2.3.1 Markerless augmented reality

Schechter [7], define the term "markerless augmented reality" (AR) as a software application that can overlay 3D virtual content into a scene and fix it to a specified location in space without requiring previous information in the form of an image. Marker-less AR may identify objects or distinguishing features of a scene, like walls or roads, without having any previous information of the surroundings. This technique, which splits the difference between augmented reality and image editing, is obviously not proven. However, it's simple and quick to deploy for applications that want to provide offline augmented reality rather than live experiences.

2.3.2 Marker-based augmented reality

In marker-based AR applications, objects are placed in specific locations using target images, also known as markers [8]. These markers specify where the digital 3D content will be displayed in the inside user's field of view. The virtual object won't appear if the camera is not correctly focused. A system for identifying images, therefore, consists of many modules, such as a camera, images taken, image recognition, marker detection, etc. Typically, this is a straightforward and low-cost method to include filters through exciting technology to detect patterns through such a camera.

2.4 Gamification - trivia

Gamification, in its wider definition, refers to science and technology, economic, social, and societal advancements that make reality more game-like and, as a result, enable people to develop skills, reap motivational advantages, be creative and playful, be engaged, and encounter positive overall growth and happiness [9]. According to Sanchez [10], the current study showed that gamification can have good short-term benefits and demonstrated how interpersonal characteristics might affect gamification's favourable long-term impacts. These findings shed light on the potential of gamification to revolutionize the educational landscape by fostering motivation, interactivity, and growth among learners.

2.4 Comparative Analysis

In this section, a comparison has been made between existing applications, such as Know Our Anatomy App [11], The Brain AR App [12], The Brain Anatomy Pro App [13] and the BrainARnatomy, proposed application. Figure 1 shows the main menu interface of the three existing applications. Meanwhile, eight features have been discussed, as shown in Table 1. It includes the type of approach technology, module, purchasing, platform, internet connection, button placement, sound effects, and background music.

The proposed application, Brain anatomy, is developed on the Android platform using the Augmented Reality maker-based technique. It is a free application, requiring no payment from users, and compatible with Android devices running version 8.0 or later. The application consists of two modules: the quiz module and the AR learn module. To enhance the overall experience, features such as background music, sound effects, and narration are incorporated, accompanied by clear instructions at the beginning of each module. Users can download flashcards to deepen their anatomical knowledge. The application maintains a consistent design and placement of buttons for a cohesive user experience.

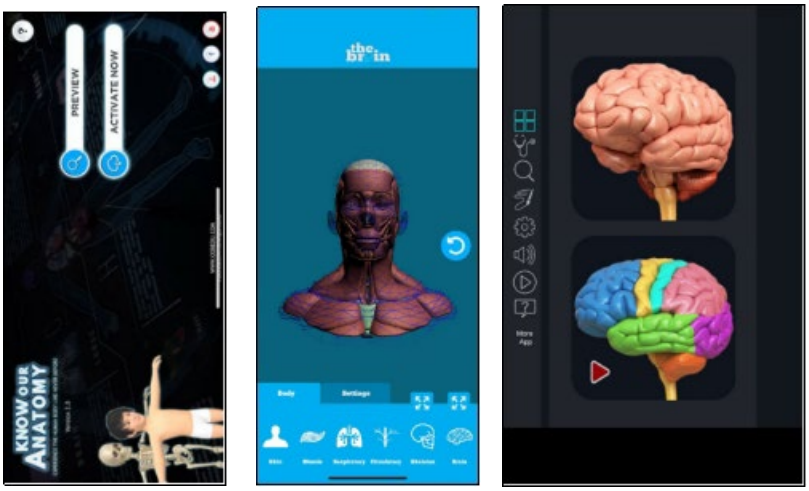


Figure 1(a): Know Our Anatomy App [11] Figure 1(b): The Brain AR App [12] Figure 1(c): The Brain Anatomy Pro App [13]

Table 1: Comparison between existing applications and proposed applications.

Element	Know Our Anatomy App [11]	The Brain AR App [12]	The Brain Anatomy Pro App [13]	BrainARnatomy, proposed application
Type of approach technology	Marker-based.	Marker less-based.	Non-AR (3D models only).	Marker-based.
Module	AR module and learn module.	Learn module.	Learn module.	AR module and learn module.
User support	Available.	Not available.	Not available.	Available.
Purchasing	In-app purchasing	Free to use.	In-app purchasing	Free to use.
Platform	Android 8.1 above and IOS 11.0 above.	Android 8.1 above and IOS 11.0 above	Android 8.1 above and IOS 11.0 above	Android 8.1 above and IOS 11.0 above
Button placement	Consistent.	Inconsistent.	Inconsistent.	Consistent.
Sound effect	Not available.	Not available.	Not available.	Available.
Background music	Light music.	Not available.	Not available.	Light music.

3. Methodology

BrainARnatomy, an AR mobile app, was developed for learning brain anatomy using the Multimedia Mobile Content Development (MMCD) approach [14]. Figure 2(b) demonstrates slight modifications to the MMCD stages, excluding the "update the structure" substage. After completing the second phase, the project will proceed directly to the process design step without updates. This is because it is not intended for this project to be updated and moved to the phase of developing the application idea after completing the second phase. Instead, the project will go on to the process design step after the navigation and object analysis are finished. The following subsections detail each stage of the MMCD approach.

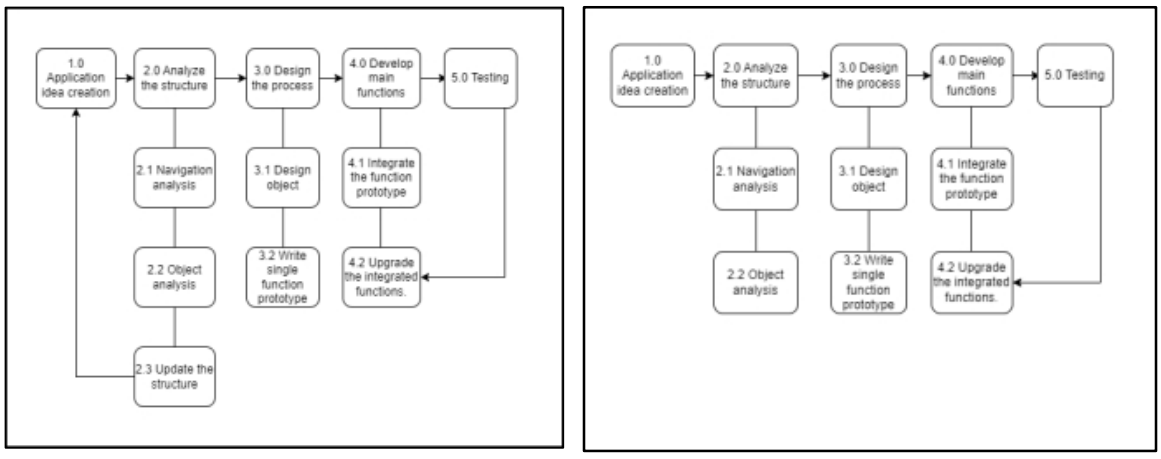


Figure 2(a): MMCD Methodology [15] Figure 2(b): Modified MMCD Methodology

3.1 Application Idea Creation Stage

The Application Idea Creation Stage involves gathering data and conducting research on augmented reality. The methods employed to identify user requirements are online interviews with Subject Matter Expert (SME) explained in Appendix A in Table 7 and 8. The data collected during these sessions helps identify areas for improvement and additions to the application. Appendix A includes a table with the questionnaire and its explanation. With the concept of the augmented reality application finalized, the

necessary information is prepared before proceeding with the design and development phases. This phase establishes user demands and application requirements. Table 2 provides an overview of the application idea development phase.

Table 2: Application Idea Checklist

Item	Description
Type Of Application	Mobile
Target User	10 years old children
Target Device	Android
Unity	• Version 2019.4.16f • Free aspects
Vuforia	Enable creation of AR app
Canva	• Design 2D background • Design 2D button • Design AR marker • Design application assets
Blender	• Create 3D model. • Texturing the model
User Interface	Background (main page, subpage)
Picture	2D image (info page)
Application Synopsis	An AR-based mobile learning application called BrainARnatomy is available to Malaysian children ages 10 years old. This application is meant to increase awareness of brain anatomy and as extra learning material for further information sources. Multimedia elements are incorporated into the teaching and learning process. The program's interactive AR module and 2D quiz are intended to improve kids' interest in and motivation for this subject.

3.2 Structure Analysis Stage

The structure of the application to be built is examined in the second step of the MMCD process. The analysis of the navigation and objects has been completed. The navigation framework can be shown in Figure 3(a) and content structure also application modules diagram are displayed in Appendix B. Figure 4 displays the application's flowcharts. For figure 4(a). Appendix C contains a reference to the content organization. Tables 3 and 4 list the functional and non-functional criteria, respectively.

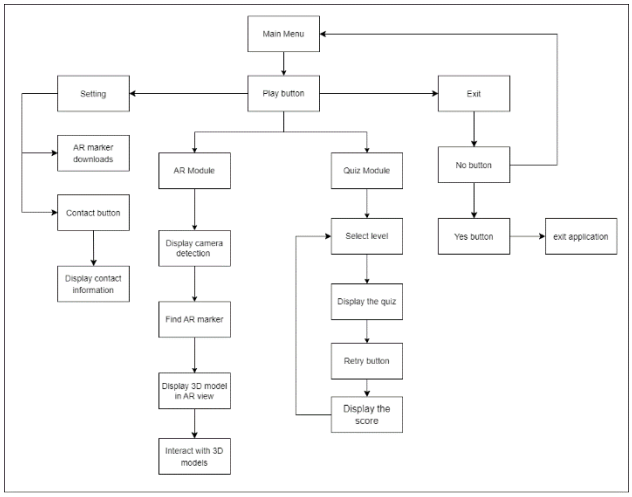


Figure 3(a): Navigation Structure

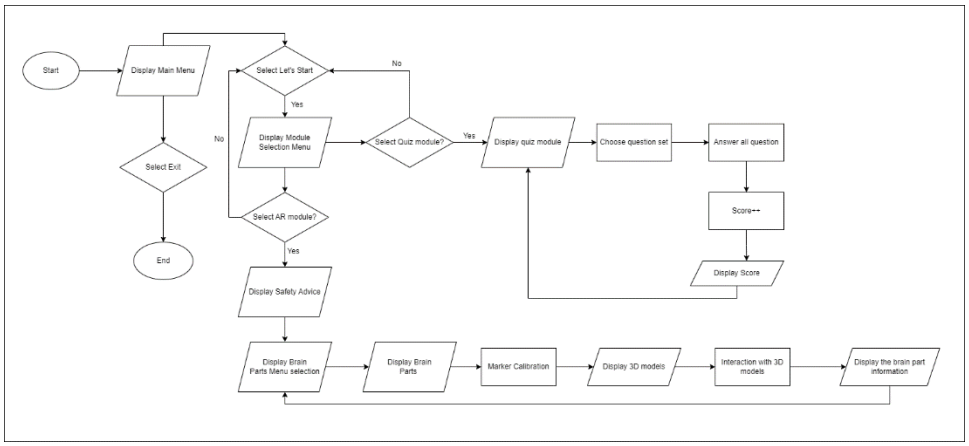


Figure 4(a): System flowchart

Table 3: Functional requirements

Functional requirement	Module	Description
User interaction support	Main menu module selection	• The application should allow users to select a module by clicking on it. The application should allow users to navigate through the application by using the right button.
	AR module	• The system should allow the user to click each part of the brain. • The system should allow the user to close the description of each part of the brain.
	Quiz module	• The system should allow users to give input by selecting and clicking the part of the brain as the answers of the quiz. • The system should allow users to play the quiz again by clicking the retry button.
	Setting module	• the system should allow users to download AR markers, give instructions for the first user using AR and be able to contact us for inquiries.

Functional requirement	Module	Description
Provide Learning Content	AR module	• The system should allow users to learn the part of the brain. • The system should allow users to identify the different brain areas in the brain anatomy. • The system should allow users to know each part of the brain's information in the brain anatomy through description form and audio form
	Quiz module	• The system should enable users to gain a better understanding of the anatomy of the brain. • The system should allow users to identify the part of the brain as the answer to the quiz. • The system should allow users to understand the environment of the brain anatomy.
Autonomous System Activities	AR module	• The system shall display the 3D brain model after users calibrated the marker.
	Quiz module	• The system will decide if it is the right answer while the quiz is ongoing. • The system will determine the quiz's overall grade at the conclusion.

Table 4: Non-functional requirements

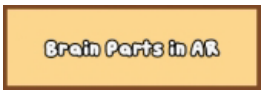
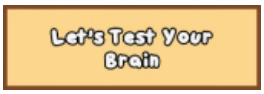
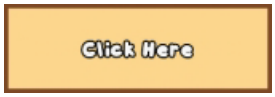
Non-Functional requirement	Description
Efficiency	• The application shall be fast responding which is less than 1 second for most Android mobile that fulfill the system requirement. • The application shall operate completely offline.
Usability	• The flow is easy and simple for children to understand. • This application should be easy to use, efficient, and enjoyable for the user. • Users can use this application from anywhere at any time
Availability	• The application and its data should be able to be accessed without the internet.
Implementation	• This application should be easy to use, efficient, and enjoyable for the user. • Users can use this application from anywhere at any time.
Legal	• Users are only able to view the data presented by the application; they cannot alter it.
Cultural	• The application should be developed using the English language.

Non-Functional requirement	Description
Graphical User Interface Support	• This application must support all of its elements, including text, images, and audio, for different Android mobile device display resolution sizes.

3.3 Process Design Stage

The third element of the MMCD technique is to design the process. Two sub phases of this level are object design and writing the single function prototype scripting. At the conclusion of this procedure, the prototypes for the AR and quiz modules will be finished. In this project, storyboards, 2D and 3D animations, and pictures are all created using authoring tools like Blender, and Canva. Scripting is used to build the assets while using the Unity software.

Table 5: Button design

Button	Description	Button	Description
	This is a start button.		This is an exit button.
	This is an important function information button.		This is a best way to improve information button.
	This is AR module button.		This is quiz module button.
	This is AR marker button that user can download AR marker.		This is How to Use AR button that give guide how to interact with AR model.
	This is the Click Here button which is an instruction before user ready to play AR module.		This is the Yes button in exit page as confirmation to end the apps.
	This is a No button in the exit page as confirmation to return the apps.		This is a setting button.
	This is a music button (on).		This is the music button (off).
	This is a previous button.		This is the question button.

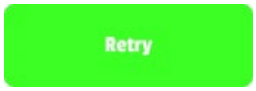
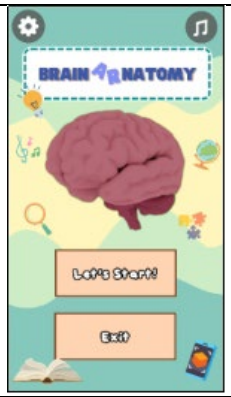
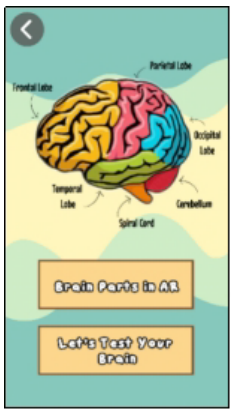
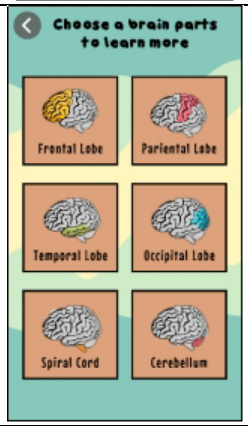
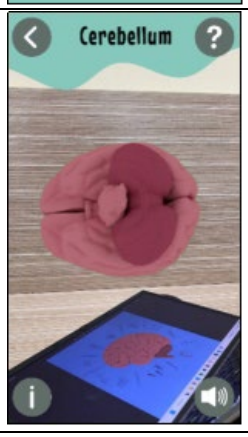
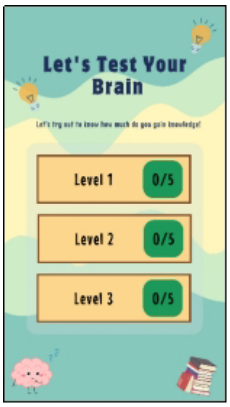
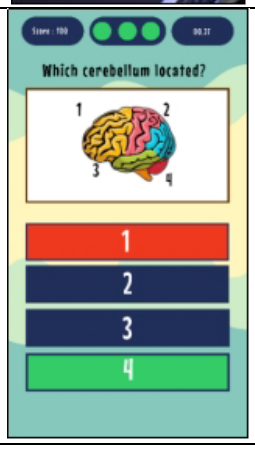
Button	Description	Button	Description
	This is an audio button.		This is a close button.
	This is an information button.		This is a retry button.

Table 6: Interface Design

Interface	Description	Interface	Description
	This is the startup interface of the proposed application. The user clicks the next button to go to the module menu.		This is a setting page. It provides an AR marker for a user to detect the AR. Then, the user can click on How to use AR for the first user who does not know how to use AR app. The last is the Contact button for user need inquiries.
	This is a module page that contains the AR module button and quiz button.		This is a brain parts page which user need to click to know each part of AR and information about each brain parts.
	This is AR calibration; it will pop up the text if user not scanning the AR marker.		This is AR calibration; it will pop up the 3D model after user successfully scan the AR marker.

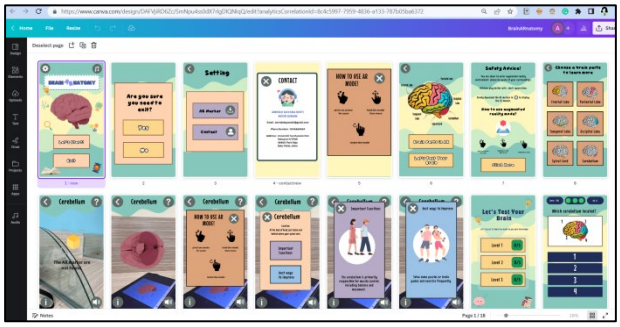
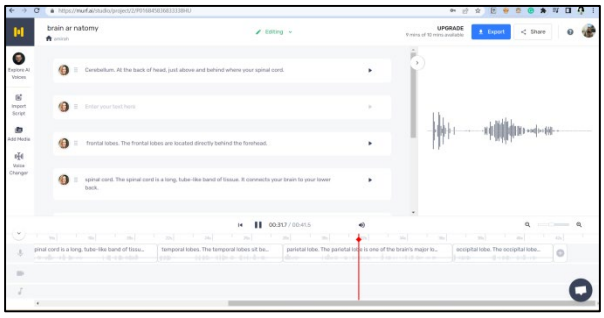
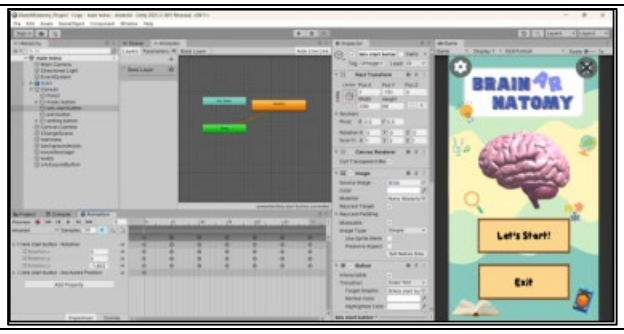
Interface	Description	Interface	Description
	This is an information pop up page after user click on information button.		This is a quiz module users can select the levels. Each level contain different questions about brain parts.
	This is the quiz page that user interact such as the true and wrong answer colored, the score, lifeline and timer display.		This is a complete pop-up page after user answered all the question. The score are saved in quiz module interface.

3.4 Main Function Development Stage

In this phase, the main functions of the proposed application are developed. It involved developing assets for the application and the integration of the assets into Unity software. There are 4 multimedia elements developed as assets of the application. It consists of audio, graphics, 2D animations, and 3D animations, as tabulated in Table 8.

Table 7: Application Assets Development

Assets	Development	Description
3D model		The development of 3D objects is done in Blender software. Among the developed objects is the part of the brain that has 6 separate positional parts. To distinguish them, the part of the brain is coloured with a strong colour such as red so that the user can know that they are studying that part.

Assets	Development	Description
Graphic		Canvas was utilized to create graphic elements for BrainARnatomy. Its user-friendly design tools and template library made it suitable for developing application interfaces. Since the target audience is 10-year-old children, visually appealing graphical assets were essential to capture their attention.
Audio		The BrainARnatomy audio was recorded using Murf AI, a text-to-speech AI voice generator. Murf AI, also known as Murf Studio for voice generation, can quickly produce realistic voiceover narrations for written material. This technology enhances learning apps by providing customized voice models, improving accessibility, pronunciation practice, and creating immersive learning environments.
Animation		The animation process involves a 'Let's Start' button that prompts user interaction. To enhance interactivity, the button utilizes rotation properties, moving left in the first keyframe, right in the second keyframe, and remaining stationary for 30 frames.

Furthermore, the C# scripts are developed to enable the main functions of the application Features such as show and hide panel, exit function, load function, pop up description panel, generate questions and answer, update and answer, update quiz score, update background music button, and AR develop are explained briefly here. These functions are explained in Table 8. Meanwhile, the interfaces of the developed application are presented in Table 9.

Table 7: Integration in Unity

Functions	C# Scripts	Description

Show and Hide Panel	`using UnityEngine;`
	`using UnityEngine.UI;`
	
	`public class PopupManager : MonoBehaviour`
	`{`
	`public GameObject popupPanel;`
	`public Button openButton;`
	`public Button closeButton;`
	
	`private void Start()`
	`{ openButton.onClick.AddListener(OpenPopup);`
	`closeButton.onClick.AddListener(ClosePopup);`
	`}`
	`private void OpenPopup()`
	`{popupPanel.SetActive(true);`
	`}`
	`private void ClosePopup()`
		The "PopupManager" class in a Unity game defines three variables: "popupPanel" (representing a popup panel), "openButton" (used to open the popup), and "closeButton" (used to close the popup). The "Start()" function sets up event listeners for the "openButton" and "close Button," triggering the corresponding functions "OpenPopup()" and "ClosePopup()" when clicked. "OpenPopup()" makes the "popupPanel" active and visible, while "ClosePopup()" makes it inactive and hidden. This code

Functions	C# Scripts	Description
	{popupPanel.SetActive(false); } }	allows the user to control the visibility of a popup panel by clicking the open and close buttons.
Load Scene Function	using System.Collections; using System.Collections.Generic; using UnityEngine; using UnityEngine.SceneManagement; public class changeScene : MonoBehaviour { public void btn_change_scene(string scene_name) { SceneManager.LoadScene(scene_name); }}	In a Unity game, the "changeScene" class is defined by this code. The public function "btn_change_scene" on it accepts the string parameter "scene_name" as a parameter. This function uses Unity's "SceneManager" class to load a new scene depending on the "scene_name" argument when it is called. In essence, this code enables the user to go to a different scenario or level in the game by pressing a button.
Exit Function	using System.Collections; using System.Collections.Generic; using UnityEngine; public class SceneLoader : MonoBehaviour { public void QuitGame() {Application.Quit(); Debug.Log("Quit"); }}	In a Unity game, the "SceneLoader" class is defined by this code. It has a "QuitGame" public function that executes two operations. The "Application.Quit()" method is the first thing it calls, and it closes the gaming programme. Second, for debugging purposes, it prints the word "Quit" to the Unity console using the "Debug.Log()" function. This code offers a means to end the game when the "QuitGame" function is called, ending the game application, and logging the event.

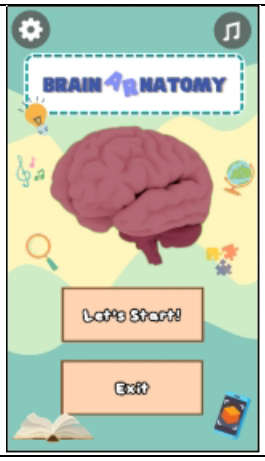
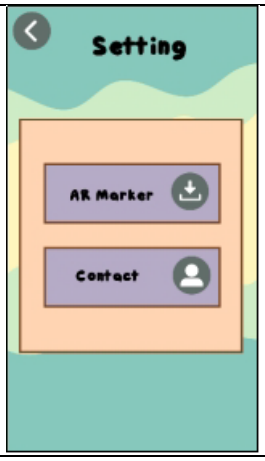
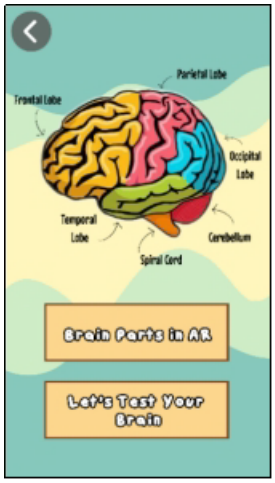
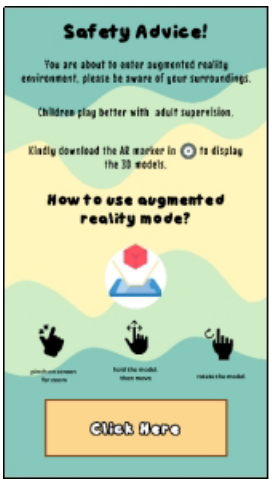
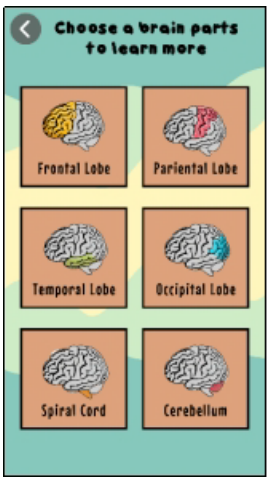
AR calibration	protected virtual void HandleTargetStatusChanged(Status previousStatus, Status newStatus)
	{
	var shouldBeRendererBefore = ShouldBeRendered(previousStatus);
	var shouldBeRendererNow = ShouldBeRendered(newStatus);
	if (shouldBeRendererBefore != shouldBeRendererNow)
	{
	if (shouldBeRendererNow)
	{OnTrackingFound();
	}
	else
	{OnTrackingLost();
	}
	}
		The code defines a protected virtual method called "HandleTargetStatusChanged" that takes two parameters: "previousStatus" and "newStatus" of the "Status" class. Inside the method, two variables, "shouldBeRendererBefore" and "should Be Renderer Now," are declared to determine if the target should be rendered based on the old and new statuses. If there is a change in rendering status, it checks if the target should be rendered immediately. It invokes the "OnTrackingFound()" function if rendering is required and the "OnTrackingLost()" function if it is not. Essentially, this function manages target status changes and triggers appropriate actions based on rendering status, such as tracking target found or lost.

Change background music UI button	public void OnButtonPress()
	
	{
	if (muted == false)
	{muted = true;
	AudioListener.pause = true;
	}
	else
	{muted = false;
	AudioListener.pause = false;
	}
	Save();
	UpdateButtonIcon();
	}
		The code defines a public method called "OnButtonPress" that toggles the audio mute status when a button is pressed. If "muted" is currently false, the method pauses audio playback by setting "AudioListener.pause" to true and sets "muted" to true. If "muted" is already true, the method resumes audio playing by setting "AudioListener.pause" to false and sets "muted" to false. The method then calls "Save()" and "Update Button Icon()" to save the state and update the button's visual icon accordingly. This code provides audio mute

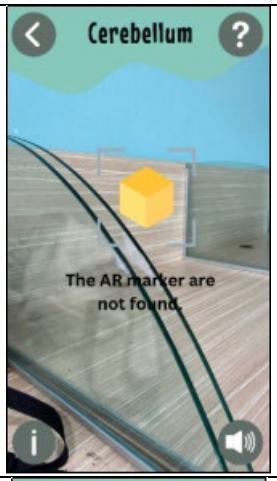
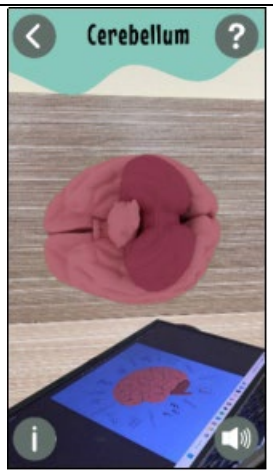
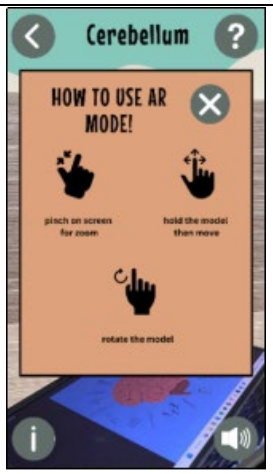
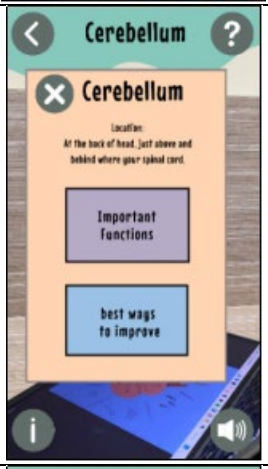
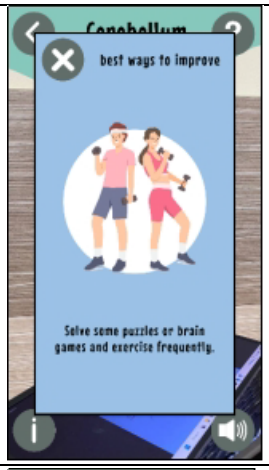
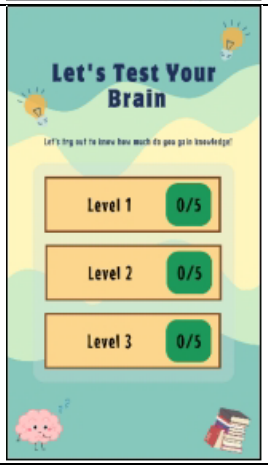
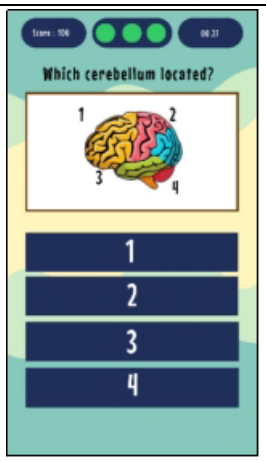
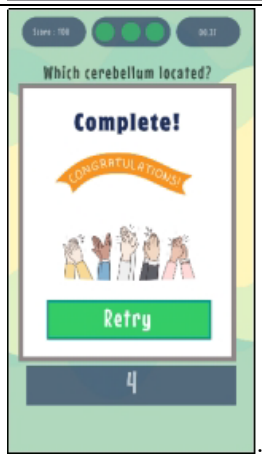
Functions	C# Scripts	Description
		functionality and updates the button and state accordingly.

Life system (quiz module)	`public bool Answer(string selectedOption)`
	`{//set default to false`
	`bool correct = false;`
	`//if selected answer is similar to the correctAns`
	`if (selectedQuetion.correctAns == selectedOption)`
	`{//Yes, Ans is correct`
	`correctAnswerCount++;`
	`correct = true;`
	`gameScore += 50;`
	`quizGameUI.ScoreText.text = "Score:" + gameScore;`
	`}`
	`else`
	`{//No, Ans is wrong, Reduce Life`
	`lifesRemaining--;`
	`quizGameUI.ReduceLife(lifesRemaining);`
	`if (lifesRemaining == 0)`
	`{GameEnd();`
	`}}`
	`}`
		The "Answer" public method, which receives the string parameter "selectedOption" and returns a boolean value, is defined in this code. A boolean variable called "correct" is initially set to false inside the method. The chosen alternative is then compared to the right response to the chosen question by the code. If so, the score is updated, the number of correct answers is increased, and the "correct" variable is set to true. If the chosen option is incorrect, it decreases the number of lives left, adjusts the user interface to reflect the decreased lives, and determines whether there are any lives left after zero. The "GameEnd" function is invoked if they have.

Table 8: Interface of the developed application

Module	Interface		
Main menu interface			
AR module interface			

.

Module	Interface		
AR calibration interface			
Information interface			
Quiz module			

3.5 Testing Stage

In the last phase of the MMCD methodology, two types of testing will be performed, functional testing and user acceptance testing. If bugs are discovered in this phase, the project will return to the previous phase to update the integrated functions to fix the bugs. The functional testing is presented in Table 9, while the user acceptance testing is discussed in Section 4.

Table 9: Alpha testing results.

Test	Expected Result	Actual Result	Corrective Action
Navigation button	Navigates to each interface.	Works well as expected.	Not needed.
Audio button	Play the audio.		
Close button	Close the pop-up panel.		
Music Button	Play and mute the music background.		
Question button	Display the how to use AR pop-up panel		
Information button	Display the information bran parts pop up panel		
Question button	Retry the exercise.		
Animation	Play the animation	The animation is not played in awake and not in the loop.	The selection has been changed through the Inspector panel.
AR calibration	The calibration changes for the AR marker are not found' to display the 3D model brain parts.	Works well as expected.	Not needed.
AR interaction	The interaction such as rotate, scale, and drag are functional.	The interaction is not working although has done put Lean Touch.	The background of AR calibration layered the 3D model. The background has been cropped.
Score System	Track the current score and record the highest score of the exercises.	Failed to track the highest score when playing a new exercise.	PlayerPrefs.GetInt() is called in all score managers.

Table 9 shows that a few errors were spotted. In the main menu, specifically on 'Let's Start button', the selection has been changing through the Inspector panel, so the looping continued and not anymore played once only. Furthermore, the layer of the canvas caused the problem. The background of AR calibration layered the 3D model. The background has been cropped and the interaction is already functional. Additionally, the PlayerPrefs.GetInt() command is used to get around the high score system's weakness to keep track of the highest score received during the quiz. Lastly, an issue occurred in the Android while generating the project's APK. This is due to a conflict with publishing settings. This is addressed by creating the password, so whenever user need to generate APK, inserting password is required.

4. Results and Discussion

This section presents the findings of the user acceptance testing conducted for the developed application. The Technology Acceptance Model (TAM) [15] was used as the framework for the assessment. The application was distributed to 10 respondent which 10-year-old target users via Google Drive, accompanied by a Google Form questionnaire. The questionnaire evaluated perceived learning outcomes (LO), functional usability (FU), user acceptance (UA), and overall performance (OP). Multiple-choice options, including 'yes,' 'no,' and 'maybe,' were provided. During testing, the teacher assists in selecting students of the target age group and creates a comfortable testing environment. She introduces the session, explains the purpose, and gives clear instructions. The teacher addresses any

concerns and facilitates a feedback discussion afterward. They ask open-ended questions, encourage student participation, and share their observations.

Regarding learning outcomes in Figure 5, an average of 60% of respondents agreed that they understand how to use this app especially when scanning using images and interacting with 3D models of the brain. However, it also received 30% that choose ‘maybe’, It is possible that the person asking the question is not completely sure if it is indeed possible to identify and understand each function of brain parts and gain knowledge about them. There 10% choose ‘no’, still not accustomed to using augmented reality applications. For functional usability in Figure 6, 80% of respondents agreed that the app had no issues or bugs, while 20% chose 'maybe,' suggesting that there is a possibility that the application could have problems or bugs, but the person asking the question is not entirely sure.

Based on user acceptance in Figure 7, 80% of respondents agreed to enjoy interacting with 3D models of the brain. However, 20% choose ‘maybe’, in this case, they are confused about whether to interact with the 3D models. For overall performance in Figure 8, an average of 40% of respondents agreed that all interfaces are nicely located. However, it also received 30% that choose ‘maybe’, It is possible that the person asking the question is not completely sure if it is indeed possible, they are confused about whether the interface is in an acceptable position or not. 30% choose ‘no’, which means that all interfaces are not located nicely. It is due to the different screen sizes of phones that they use and the screen size that has already been set during the development process.

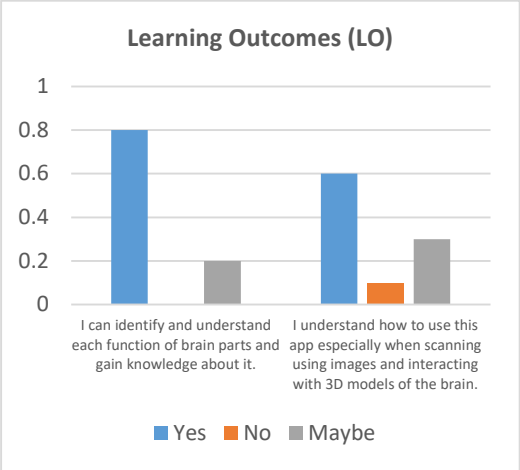


Figure 5: Analysis of Learning Outcomes

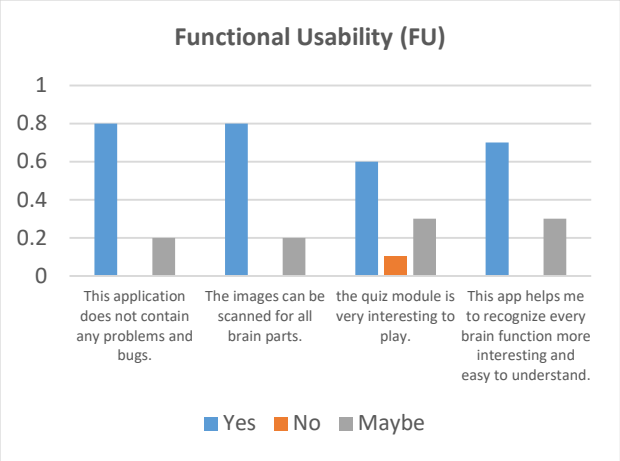


Figure 6: Analysis of Functional Usability

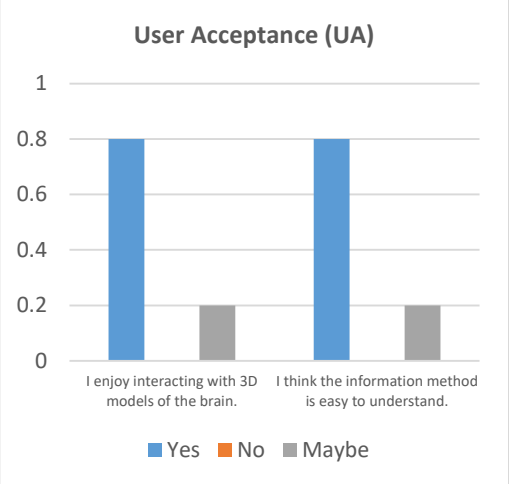


Figure 7: Analysis of User Acceptance

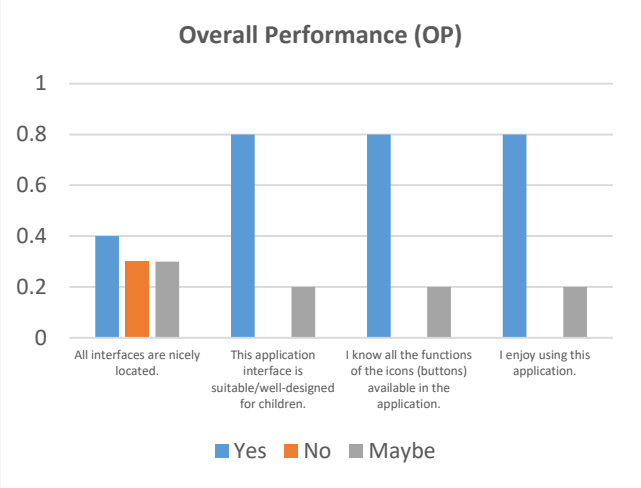


Figure 8: Analysis of Overall Performance

5. Conclusion

In conclusion, the proposed project aims to develop the mobile learning application "BrainARnatomy." This application focuses on visualizing brain anatomy using augmented reality (AR) for children. It targets users who seek to enhance their understanding of the human brain through interactive learning materials. The main goal is to raise awareness about the brain and boost children's confidence by teaching them how it functions. By leveraging AR technology, the BrainARnatomy app provides a dynamic and engaging learning experience. The inclusion of quizzes enhances user learning through interactive and gamified elements. The project followed a well-planned Multimedia Mobile Content Development (MMCD) process and incorporated valuable user feedback through testing. The objectives of the project were successfully achieved, addressing the lack of multimedia components and child-friendly learning modules found in existing applications on the Google Play Store. Future improvements will focus on utilizing augmented reality and introducing dynamic quiz content to further enhance the suggested application.

Acknowledgment

I would like to thank the Faculty of Computer Science and Information Technology, University Tun Hussein Onn Malaysia for their support.

Appendix A

Table 7: Interview question for SME.

Number	Question
1.	Is it possible to design a brain-related application that can give a 10-year-old child awareness?
2.	How to emphasize this lesson about brain anatomy even though it is not covered in the syllabus?
3.	Is this educational material suitable to be developed using an augmented reality method for children aged 10 years old?

Table 8: User requirements analysis explanation.

Element	Explanation
Lesson appropriateness	• Children's knowledge of the importance of acquiring social-emotional skills and how they support their brain development can be directly impacted by the brain anatomy study, making it appropriate for additional learning applications. • Children do not use any other learning resources in class; they are only exposed to the books.
Aim of Lessons	• Helping children to identify the differences between parts of their brains and finding out how they can improve or take care about it. • Children shall develop the skills essential to manage their learning, health, and well-being through brain-aware practices, giving them the ability to create favourable outcomes for themselves.
Use of Augmented Reality Approach	The usage of augmented reality technology in this lesson was appropriate since it helped children learn the material by presenting a realistic environment for them to learn in.

Design appropriateness	The content should be trustworthy, uses simple words, and benefits from one syllabus term.
Conclusion	Target users were interested in using the BrainARnatomy application.

Appendix B

This section presents the content structure and flowchart mentioned in Section 3.1.

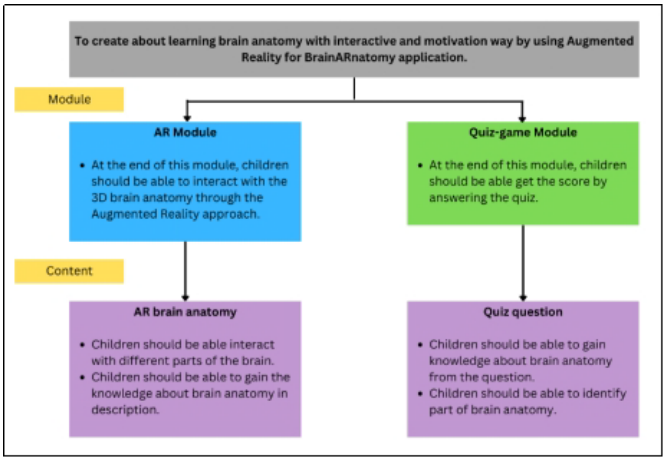


Figure 3(b): Content structure of BrainARnatomy application

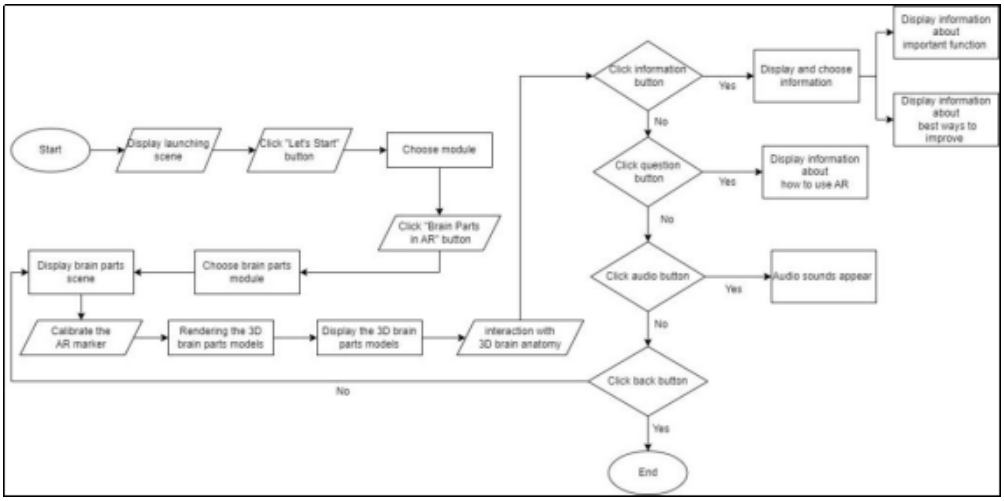


Figure 4(b): Flowchart for AR module

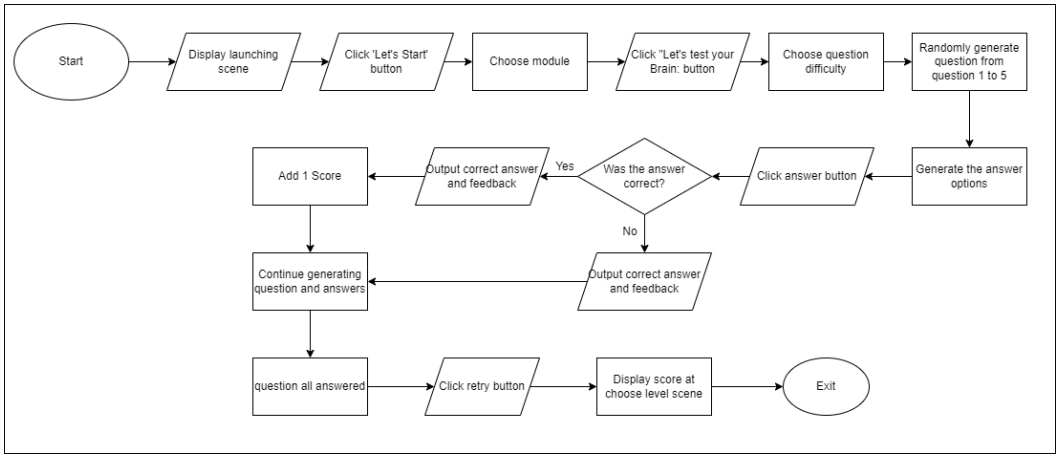


Figure 4(c): Flowchart for Quiz module.

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