

AR Nutri Food: The Development of an Augmented Reality Mobile Learning Application

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Abstract

The "AR Nutri Food" project aims to develop an advanced mobile application to enhance the teaching of nutrition and food to Year 3 primary school students. The Year 3 Science curriculum's "Classes of Food" topic lacks digital resources, such as videos and audio, due to space constraints. This limits effective teaching and student understanding, as modern children are more engaged with interactive content. The application employs Augmented Reality (AR) technology to construct an immersive and interactive learning environment. It includes interactive content and gamified elements to provide a comprehensive learning experience for young users. The project report will provide a detailed analysis of "AR Nutri Food", including its relevance, advantages, and limitations, as well as its potential impact on primary education. The Multimedia Mobile Content Development (MMCD) methodology was selected for the creation of the application. The project is a significant contribution to digital learning tools, particularly in primary education. Year 3 primary school students participated in a testing session to evaluate the application's user acceptance, functionality, and efficiency. The application received the positive feedback from target users during the testing phase.

1. Introduction

Augmented Reality (AR) is a technology that blends virtual elements with the physical world, enhancing our surroundings with computer-generated sensory data. AR is used in various industries, including gaming, navigation, manufacturing, and especially education. In education, AR is used to create interactive and immersive learning experiences that enrich our understanding of the subject matter [1]. AR has demonstrated its effectiveness in educational environments, leading to enhanced learning outcomes, increased motivation, heightened enjoyment, and greater learner independence [2]. This impact is particularly pronounced in subjects that demand comprehension of intricate concepts and areas such as nutrition, where the need for engaging visualization is paramount [2][3][4].

Early exposure to nutrition education is essential for children's health and well-being. Eating a balanced diet can help prevent health issues such as childhood obesity and influence children's eating habits [2][3][5]. Traditional methods of teaching nutrition, like textbooks, videos, and mobile apps, have limitations. Integrating augmented reality (AR) into mobile learning apps can make learning more engaging and enjoyable for children, providing a fun and effective way to teach healthy eating [4]. The use of AR applications can facilitate the education

of children regarding the various food groups and the significance of consuming a diverse diet. [4]. The development of interventions that promote healthy eating habits and a balanced diet among children is essential [4].

In an interview with SME Cikgu Aidah, it was found that the Year 3 Science curriculum lacks digital resources for the topic "Classes of Food" due to space constraints in textbooks. This limitation affects effective teaching and student comprehension. Developing interactive digital content can address this gap, offering a more comprehensive learning experience and deeper understanding of scientific concepts. Interactive learning experiences can enhance children's motivation and enrich education. However, existing nutrition apps for primary school students lack interactivity and have complex information. Interactive learning with hands-on activities and games can significantly boost children's motivation and academic performance [6].

Dr. Perri Klass [7] suggests that educational applications can be gamified to engage early readers, and techniques such as digital annotation and structured on-screen reading enhance learning. To address the issue of decreased enthusiasm for reading compared to mobile gaming, the proposal suggests developing an application that utilizes Augmented Reality (AR) technology and interactive gameplay to encourage children's interest in nutrition education. AR is well known for its capacity to present information engagingly and interactively, promising an enhanced and more enjoyable approach to nutrition education. An interactive mobile learning game that allows children to learn about food nutrition in the context of the Science subject is suggested to develop. The objective is to make the learning process more enjoyable and efficient than traditional textbook-based or tutorial-based methods. The project also aims to promote healthy eating habits and a balanced diet among children [2].

To achieve the goal, several objectives have been set out as follows. The objectives of the present project are: (i) to design an interactive mobile learning application Nutri Food using augmented reality approach, (ii) to develop "AR Nutri Food" for Android platform using Android technology, and (iii) to perform the functionality testing using alpha testing on the developed application and beta testing to the target user. The project aims to develop an interactive mobile learning application that promotes food nutrition awareness among primary school students. The project is closely linked to the Year 3 science curriculum, with a specific focus on the "Classes of Food" topic in Chapter 3 as outlined in the Textbook Science Year. The project aims to provide an engaging learning experience, with an English-language interface, primarily targeting children aged 9-12 years old. The AR Nutri Food mobile learning application will include two function modules, which are an Augmented reality (AR) marker-based learning module and an activity module. The AR learning module will detect the markers and generate content about different classes of food on a virtual plane. The content will also cover the health benefits of seven types of food. However, the activity module provides students with an entertaining and interactive way to learn about healthy eating habits through interactive hidden object games that engage children and enhance their understanding of the different food groups.

Chapter 1 provides an overview of the project background, problem statements, objectives, scope, and significance. Chapter 2 reviews literature on augmented reality (AR) in mobile learning, informing the "AR Nutri Food" project by analyzing existing applications. Chapter 3 details the Multimedia Mobile Content Development (MMCD) methodology used, outlining stages like idea creation and testing. Chapter 4 focuses on gathering requirements for application features. Chapter 5 covers development phases of AR Nutri Food, including asset implementation, script integration, and testing. Finally, Chapter 6 evaluates project outcomes, discussing strengths, weaknesses, and future enhancements.

2. Literature Review

The literature review is a crucial aspect of researching a particular topic. In addition to reviewing relevant topics, this section will discuss and analyze several similar existing applications for reference purposes. A review highlights the necessity to encourage the adoption of healthy eating behaviours and the consumption of fruits, vegetables, and other nutrient-dense foods among children. This indicates that the term "nutritional food" is used to describe foods that are part of a healthy, balanced diet (Sindhuja et al., 2023).

2.1 Mobile Learning Application

Mobile learning, also known as m-learning emerged in the early 2000s, marking a significant development in modern education [8]. This innovative approach takes advantage of mobile devices by allowing people to access information and communicate with others from nearly anywhere provided they have an internet connection.[8] Recently, mobile learning applications have transitioned from delivering static content to more dynamic and interactive methods. This transformation is particularly noticeable in nutrition education, where modern applications use innovative technologies like augmented reality (AR) to foster more engaging and effective learning experiences. Users are increasingly favoring mobile devices due to their portability and availability

around the clock to make learning more convenient [9]. This technological advancement holds the promise of an improved future for education.

2.2 Marked-based Augmented Reality Technology

Compared to the other type of AR known as markerless AR, marker-based AR is highly precise because it links the virtual content to the markers [10]. AR markers can be printed on paper or other materials or created from digital images or patterns [11]. Marker-based AR requires AR engines to process the detection of marker and display of the associated 3D objects. Examples of AR engines include ARCore, Vuforia, Zappar, and Wikitude [10]. In mobile learning, marker-based AR improves the learning experience by adding 3D models and digital content to real-world objects or images [10]. This technology has the potential to transform how students interact with educational materials. Figure 2.2 shows an example of using a markerless AR application to display the virtual content in AR mode.

2.3 Comparison Between Existing Application and Proposed Application

This section provides an analysis of three existing applications in the market that are relevant to the proposed application. These applications include "Nutrients" by Adria Devs (2022), "Nutrition Facts and Benefits" by Agentist (2021), and "Healthy Food" by Abdurrahman Afis (2022). The evaluation of these three nutritional applications is based on several critical features to determine their overall performance and functionality. The proposed application incorporates Augmented Reality (AR) features, and includes multiple interactive media components like video, narration, and images to deliver knowledge to the user.

The section presents a comparative analysis of three existing applications, namely "Nutrients", "Nutrition facts and benefits" and "Healthy food", against the proposed "AR Nutri Food" application. The comparison table shown in Table 1 contrasts various features, including the integration of augmented reality (AR) technology, multimedia elements, user interaction, and design aspects. "AR Nutri Food" is distinguished from existing applications by its incorporation of AR features, interactive media components, and a mini-game module tailored for children. Unlike existing applications, which are primarily focused on adults and provide textual information, "AR Nutri Food" introduces unique features like a hidden object game and comprehensive navigational buttons, with the aim of enhancing user engagement and educational value. By leveraging the strengths of existing applications, "AR Nutri Food" aims to optimise functionality, usability, and overall user experience through effective design and feature integration.

Table 1 Comparison Table

Application Name	Nutrients	Nutrition facts and benefits	Healthy food	AR Nutri Food
Developer	Adria Devs (2022)	Agentist (2021)	Abdurrahman Afis (2022)	Tan Sze Jee (2023)
Internet connection	Required	Not Required	Not Required	Not Required
Game module	Not included	Not included	Not included	Include
Modules Type	Learning only	Learning only	Learning only	Learning and game
Technology used	Android	Android	Android	Android technology combined Augmented Reality
Reference Module/ Main source	Not stated	USDA National Nutrient Database	Not stated	Textbook KSSR
Target User	Public (Adult)	Public (Adult)	Public (Adult)	Children
Interactivity	Touch inputs on the screen	Touch inputs on the screen	Touch inputs on the screen	AR interactivity
Overall colour and design	Plain	Colourful	Dull and messy interface	Colourful, attractive interface design
Background music	Not included	Not included	Not included	Include good audio quality
Sound Effect	Not included	Not included	Not included	Include

Table 1: (cont)

Advertisement	Included	Not included	Included	Not included
Strength	Content scrollable	text Colourful Interface	Content scrollable	text Include Augmented Reality technology and multimedia elements such as video, voice over and narration
Limitation	Not included	Not included	Not included	Not extend support for Android versions older than 8.0
User guideline	Not provided	Not provided	Not provided	Provides clear instructions for each module
Setting panel	Not included	Not included	Not included	Include
Exit confirmation panel	Not included	Not included	Not included	Include
Navigational buttons	Not provided	Not provided	Not provided	Provide navigational button

3. Methodology

Multimedia Mobile Content Development (MMCD) was selected as the project's methodology to track the project's development progress. The MMCD methodology's features include a clear framework for each phase and a focus on the objects and content navigation as shown in Figure 1. This methodology will help the developers to accelerate the development activities because it helps developers understand which tasks should be given at each stage of the application development process for this framework [12]. The five primary components of the MMCD Methodology are the application idea creation stage, structure analysis stage, process design stage, main function development stage and testing stage.

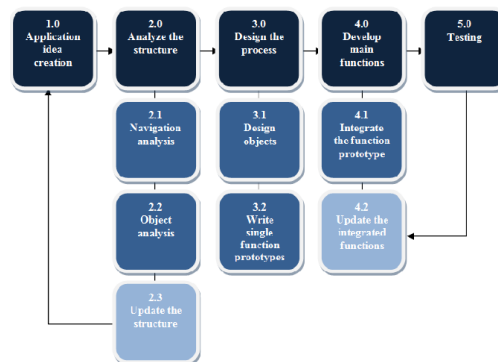


Fig. 1 MMCD Framework [12]

3.1 Application Idea Creation

The MMCD methodology's initial step is the creation of an application idea. Before creating and developing the application, the developers must gather the required information at this stage [12]. The idea created to develop mobile learning application is discussed. Table 2 displays the application idea creation checklist. Furthermore, the results of the user requirement analysis are presented in Table 3.

Table 2 Application Idea Creation Checklist

Item	Note
Type of application	Learning application
Platform	Android mobile
Target users	9-12 years old children
Graphical user interface (GUI)	Home Page interface, AR interface, Learning module, Activity module

Table 2: (cont)

Texts	Explanation in learning materials
Image	Button icons, Background image, Images of learning materials, AR image target
Video	Video as learning tutorial
Animation	Scene loading
Audio	Background music, Button clicking audio, Sound effects, Voiceover
Application summary	AR Nutri Food is a mobile learning application that allows 9-12 years old children to learn about food nutrition in the context of the Science subject using AR approach. Information of 7 classes of food will be provided and an AR approach will be implemented to make the learning process more enjoyable and efficient. Besides, activity modules will help students to test their understanding of food nutrition.

Table 3 User requirement analysis

Stakeholder Category	Role in Application	Design Implication	Action Needed
Subject Matter Expert	Expectations for content design consultants in the relevant field	Based on interview, Easy to navigate	<ul style="list-style-type: none"> To enhance understanding of button functions, use buttons with icons instead of text. The navigational structure of the application should be straightforward.
		Simple user interface	<ul style="list-style-type: none"> Use themes that appeal to children, such as vibrant colors. Clear and neat button arrangements for navigation and functionality are necessary. Instructions should be provided.

Table 3: (cont)

		Children-friendly learning	<ul style="list-style-type: none"> Use simple words and graphics for learning modules Provide simple and clear tutorials The gameplay must be simple to grasp. Use simple English as instruction. Clear graphics provided as tools for better understanding..
		Simple but reliable content	<ul style="list-style-type: none"> English vocabularies that are suitable for 9 to 12 years old children included. Avoid too wordy and complicated words. Refer to KSSR year 3 Science syllabus
		Offline feature	<ul style="list-style-type: none"> The application is accessible from any location and at any time on a mobile device. The application shall be capable of being installed and utilized on mobile devices.
		With the implementation of technology	<ul style="list-style-type: none"> The application shall be implemented with augmented reality (AR) technology.
General users (primary school students)	Target users of the application	Based on questionnaire, Usage of multimedia elements	<ul style="list-style-type: none"> The application shall be capable of being installed and utilized on mobile devices. Use more multimedia elements instead of plain texts.

3.2 Structure Analysis

In the MMCD development methodology, the structure analysis stage is the second step. Navigation analysis and object analysis are important in making the whole MMCD methodology become well-structured and comprehensive [12]. The navigation structure of AR Nutri Food and the content structure shown in Appendix. Requirement analysis is crucial in any project as it serves as a guideline and minimises the chances of errors during

application development. It involves identifying both functional and non-functional system requirements in Table 4 and Table 5. A flowchart is a diagram that illustrates the workflow or process of an application. It shows completion of a job step-by-step. Therefore, through a flowchart, an initial overview can also be distributed clearly. The flowchart displays the flow of each process, as shown in the Appendix.

Table 4 *The functional requirement of AR Nutri Food*

Functional Requirement	Module	Description
Autonomous System Activities	Main Menu	<ul style="list-style-type: none"> The home page background will appear automatically when the application is launched.
	Learning (AR)	<ul style="list-style-type: none"> When the user runs the augmented reality (AR) view for the first time, the system will request camera permission. The system will recognize the marker and display the related interface while the user scans it. The application must combine real-world elements with computer-generated content to provide a realistic learning experience for users. The application should be able to deliver audio to enhance the user's learning experience.
	Activity	<ul style="list-style-type: none"> The system will automatically detect the correctness of the option selected by users in the game module. The system will display the win or lose panel automatically once the specific condition is fulfilled.
User Interaction	Main menu	<ul style="list-style-type: none"> The application should enable users to identify text and graphics related to food nutrition. The application should enable users to understand the seven classes of food and their nutritional values. Users should be able to mute or unmute the background music by tapping the designated button. The system shall play the sound according to the sound button selected by the user. The application shall provide users with the ability to exit the application by clicking the "yes" button on the exit confirmation panel.
	Learning (AR)	<ul style="list-style-type: none"> The system should allow users to scan AR markers using the camera on their Android mobile device. Users should be able to select specific topics and navigate back to the previous interface by clicking the 'back' button. In AR mode, users should be able to interact with the 3D model using the touch screen. The application should allow users to navigate the learning interfaces by clicking on the appropriate buttons.
	Activity	<ul style="list-style-type: none"> The application should allow users to select activity modules and interact with the interface using touch gestures.

Table 5 *The non-functional requirement of AR Nutri Food*

Non-functional Requirement	Explanation
Performance	<ul style="list-style-type: none"> The Android application must operate offline and respond to user actions within three seconds. Multimedia elements in the augmented reality (AR) view should appear approximately three seconds after scanning the marker and remain visible until the device's camera moves away from the marker.
Implementation	<ul style="list-style-type: none"> The application must be compatible with Android mobile devices running on Android 8.0 or newer.
Usability	<ul style="list-style-type: none"> The application's user interfaces should be designed to be user-friendly and easy to use, allowing users to interact with the content and features seamlessly. This will ensure a satisfying user experience.

Table 5: (cont)

Legal	<ul style="list-style-type: none"> • Users can view the information displayed on the application interfaces but cannot modify it. • They are also prohibited from altering the final output obtained at the end of the game, as well as any multimedia elements within the application.
Cultural	<ul style="list-style-type: none"> • The language used in this application will mainly be simple English language. • The application shall provide content that is suitable for 9 to 12 years old children.
Graphical User Interface Support	<ul style="list-style-type: none"> • The application shall support all multimedia elements which include graphics, video, text and audio on Android devices

A flowchart shows how an application works. It shows each step in a task and the overall process as Figure 2 shown.

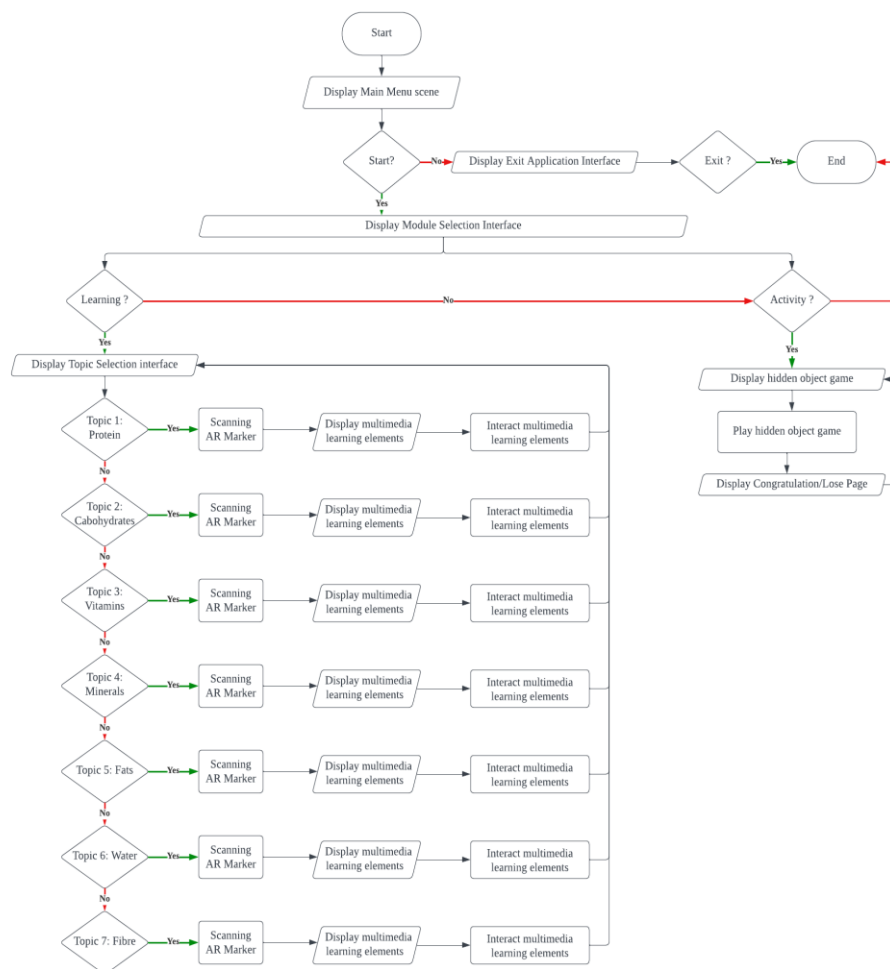


Fig. 2 Flowchart

As illustrated in Figure 4.2, users must click the “Start” button to launch the application, while clicking the 'Exit' button and to exit the application. The main menu offers two modules which are AR learning modules on various classes of food topics and activities with hidden object games. Users can scan the AR marker to interact with different multimedia content including text, videos, images, and the food pyramid. Users can choose to retry the game or return to the main menu using the back button after finish playing the game.

3.3 Process Design




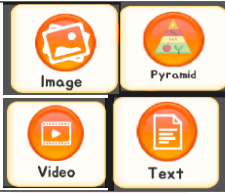







The third stage in the MMCD methodology is called process design. This stage's primary goal is to accomplish all the content structure checklist. The two substages that comprise the process design stage are write single function prototype and design objects. A number of tools are employed in the design of the object and script writing, including Unity, Blender, Canva, and Visual Studio. Table 6 illustrates the button design employed for the

proposed application. The design of all buttons was conducted using Canva, an online design tool. Table 6 illustrates the augmented reality (AR) markers for the various food categories. The 3D models of the food pyramid were created using Blender 3D, while the AR markers were generated using Canva. Both the 3D models and the AR markers are imported into Unity for the development of the AR environment. Lastly, a prototype with a single function will be well-produced with all the objects and interface design included. The ar marker will show in the Appendix.

Table 6 Button design

Button	Explanation	Button	Explanation
	Clicking on this start button in main menu interface will take the user to the module selection interface.		Clicking this home button will take the user back to the main menu interface.
	Clicking this options button will open the settings panel.		Information button
	Clicking on this exit button will display the exit confirmation panel.		Replay button is placed in the activity modules. Clicking on it allows the user to retry the game.
	Clicking this Back button will return the user to the previous interface.		Tutorial button
	Play button		Video button
	Pause button		Food pyramid button
	Mute and unmute background music and sound effect button		Camera button
	Image button		Search button
	Text button		Download button
	Deny button		Confirm button
	Level 1 button (Protein)		Learning module button
	Level 2 button (Carbohydrates)		Activity module button

Table 6: (cont)

Button	Explanation	Button	Explanation
	Level 3 button (Vitamins)		Application icon
	Level 4 button (Minerals)		Multimedia elements panel (Text, Image, Video, Food Pyramid)
	Level 5 button (Fats)		Exit confirmation panel
	Level 6 button (Water)		Information panel
	Level 7 button (Fiber)		Setting panel
	Congrats panel		

The main function development stage is the fourth phase in Multimedia Mobile Content Development (MMCD). The development of augmented reality (AR) environment in the learning module and the integration with scripting in Unity are the two primary purposes in the suggested application. Figure 3 shows implementation of the navigation function in Unity.

```

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

public class SceneManager : MonoBehaviour
{
    public void ChangeScene()
    {
        SceneManager.LoadScene("Protein");
    }
}
    
```

Fig. 3 Single function prototype

3.4 Main Function Stage

This section discusses the implementation of the application. The application consists of two main functions which are the application assets implementation, and the integration of scripting in Unity. The application assets development includes 3D models, Audio, Video, Animation Vuforia databases, and AR environments developed in Unity as shown in Table 7. The script ensures the effective functioning and seamless collaboration of application assets.

Table 7 Application assets development and Implementation of AR environment

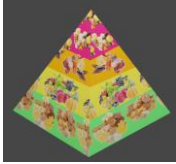
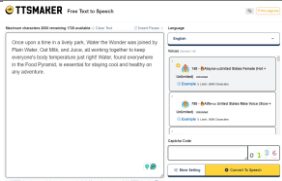
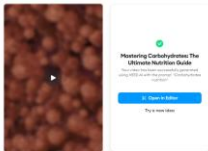
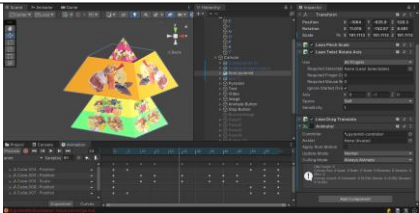
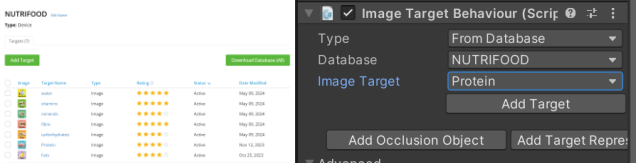
Assets	Development	Description
3D model (Food pyramid)		This 3D food pyramid model is created using Blender then textures were added to make it look more realistic and exported as fbx file and imported to Unity.
Audios		The audios for this project were created using the TTS site voicemaker.in to convert text into narration then download the audio once it's generated.
Videos		The videos have been completed using an online resource which is VEED, a software that offers functions conversion of text to video.
Animation		The animation creation process involves the creation of 3D food pyramid model then importing them into Unity to generate animation clips and create an animator controller.
Implementation of AR environment		AR Markers are uploaded in Vuforia database then imported into Unity which allow user views the 3D model in AR mode.

Table 8 Integration with scripting in Unity

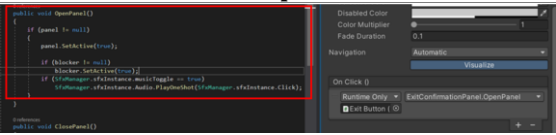
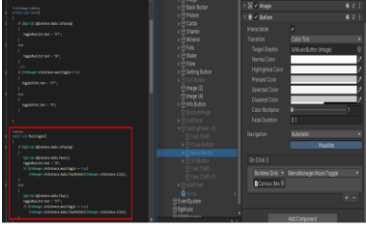
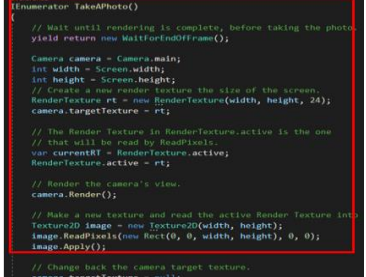
Assets	Development	Description
Show and Hide Panel		A script named exit confirmation panel cs is attached to the exit button. The exit button invokes the function of OpenPanel () where Panel. SetActive (true), which makes the exit panel active and visible.
Mute and unmute setting function		The background music menu manager script is used to control the background music. The Start Function() can check if music is on, then sets button text "ON" or "OFF". MusicToggle() function is to toggle background music between playing and paused.
Take photo Function		The "TakePhotos" script allows users to take photos from the Unity application and save them to the device's gallery for later use. TakeAPhoto() which handles the actual screenshot capturing process

Table 8 (cont)

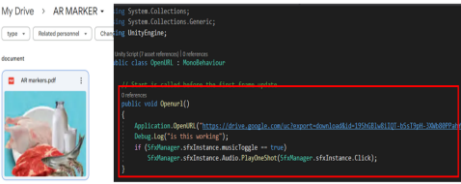
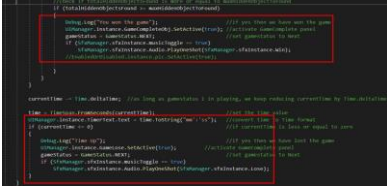

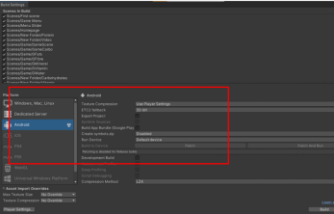
Download Function		<p>The download function script snippet include This Application.OpenURL() function to browse a specific downloadable link directly inside the code.</p>
Game Manager		<p>. If the user successfully finds all the hidden objects, the Win() function is called then the win panel will shown and plays a win sound effect. If there's running out of time, the Lose() function is called and shows the lose panel then plays the lose sound effect.</p>
Lean touch		<p>Lean Touch package is used to implement the manipulation features in AR session such as scaling, tranformation and rotation of the 3D model through the interaction between the users' fingers and the mobile device.</p>
Building setting for Andriod platform		<p>To construct the application on the Android platform, need to ensure that the Android platform is selected in the "File" followed by the "Build Settings" window. In the "Built Settings" section, it is essential to choose "Android" as the platform.</p>

Table 7 shows the development of application assets while table 8 displays the integration with scripting in Unity.

3.5 Testing Stage

The final phase in the MMCD development process is testing. The purpose of testing is to find application issues and make sure the intended user base will accept the application. Alpha testing and user acceptance testing will be carried out in this project. Throughout the development process, the developer conducts alpha testing to determine the functionality and effectiveness of the application. During the alpha testing stage, the developer assesses the functionality of the application's buttons, augmented reality (AR) system, and audio elements. Once an error is identified during testing, it is promptly rectified to ensure that all elements function as intended. The outcomes of alpha testing are based on the functionality of the buttons, AR system, and audio elements.

The user acceptance test will be taking place for the target users, 9 to 12 years old children. The main purpose of testing is to get feedback from target users about their experience using the proposed application. In this case, a set of questionnaires created using Google Forms will be distributed to the respondents along with the application apk file.

Table 9 Results of alpha testing

Test	Expected Result	Actual Result	Correction Action
Start button	Navigates to Main Menu scene.	Works well as planned.	Not needed
Option button	Shows option panel when clicked.	Works well as planned.	Not required
Learning module Button	Navigates to learning module scene.	Works well as planned.	Not needed
Activity Module Button	Navigates to activity module scene.	Works well as planned.	Not needed
Tutorial Button	Navigates to tutorial scene.	Works well as planned.	Not needed
Exit Button	Shows the exit confirmation panel when clicked.	Works well as planned.	Not needed
AR Menu Button	Navigates to AR Menu scene.	Works well as planned.	Not needed
Next Button	Shows the notes on the next scene.	Works well as planned.	Not needed
Back Button	Navigates to the previous scene	Works well as planned.	Not needed
Mute/Unmute Button	Mute or unmute the background music and sound effects.	Works well as planned.	Not needed

Table 9: (cont)

Menu slider Selection	The selected food class menu slider will go to the AR camera scene to display the 3D models.	Works well as planned.	Make sure the API level and other Player Settings meets the requirement of the Vuforia AR Toolkit.
Narrator button	Plays narration audio of corresponding food class information when clicked.	Works well as planned.	Not required.
Retry button	Retry hidden object game when clicked.	Works well as planned.	Not required.
Home button	Return to main menu when clicked.	Works well as planned.	Not required.
Info Button	Display information panel.	Works well as planned.	Not required.
Play /pause video button	Start or pause the video.	Works well as planned.	Not required.
Text/ Image/ Video/ Food pyramid interaction button	Display the particular panels	Works well as planned.	Not required.
Close button	Close the instruction interface	Works well as planned.	Not required.
Hidden object	Play the activity module scene.	Works well as planned.	Not required.
Camera button	Capture the real time image and save into gallery	Works well as planned.	Not required.
Download button	Download the AR marker pdf file from drive link provided.	Works well as planned.	Not required.

4. Result and Discussion

This section discusses the testing phase. Alpha testing is done by the developer, while Beta testing involves students aged 9 to 12. Alpha and Beta testing are used for the testing phase. The Beta testing uses the Technology Acceptance Model (TAM) to test how users accept the application. Before the testing commences, the target user is required to utilize the proposed application. A set of questionnaires was prepared in accordance with the TAM concept, comprising four distinct sections: perceived ease of use, perceived usefulness, attitude and user satisfaction. Given that the target user group is young and may lack the requisite cognitive abilities to comprehend the questionnaire items, they are asked to answer the questionnaires under the guidance of teachers. The target user must first experience the application before they are permitted to complete the questionnaires. Figure 4 and figure 5 show the pilot test procedure and real case study procedure.

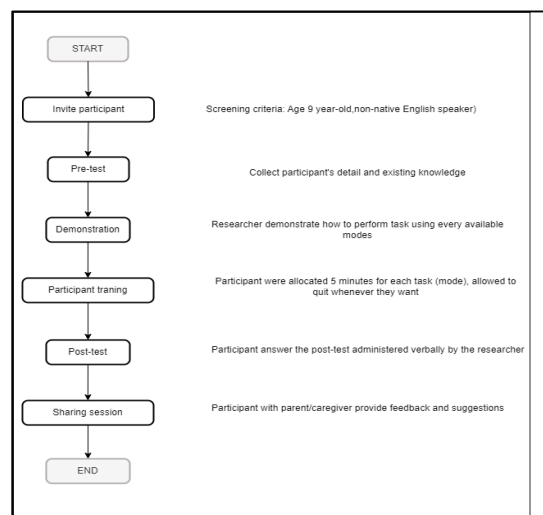


Fig. 4 Pilot test procedure

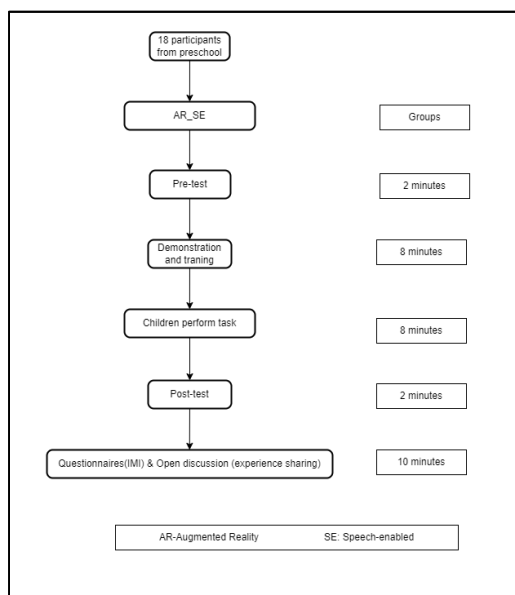


Fig. 5 Real case study procedure

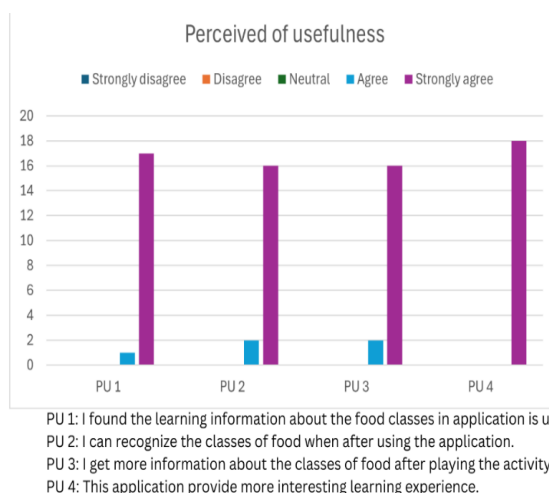


Fig. 6 Analysis perceived of usefulness

Figure 6 shows the results of a survey on how useful people perceive AR Nutri Food to be for learning about different food categories. Perceived usefulness refers to how well the app helps users learn about these categories. The survey results indicate that 17 respondents strongly agreed, and 1 respondent agreed that the information about food categories in the application is useful for learning. Additionally, 16 respondents strongly perceived AR Nutri Food as a helpful tool for recognizing food categories, with 2 respondents agreeing. Furthermore, 16 users strongly reported being able to learn more about food categories after playing the activity module, while 2 respondents agreed. All 18 respondents strongly agreed that the application provides a more interesting learning experience.

The six questions on perceived usefulness (PU) aim to evaluate how well the application educates users about food classes, enhances their knowledge, and provides an engaging learning experience. They assess the usefulness of the information, the effectiveness of AR features and activity modules, and compare the application's learning benefits to traditional methods. Overall, these questions gauge the application's value in improving users' understanding and making learning more interesting.

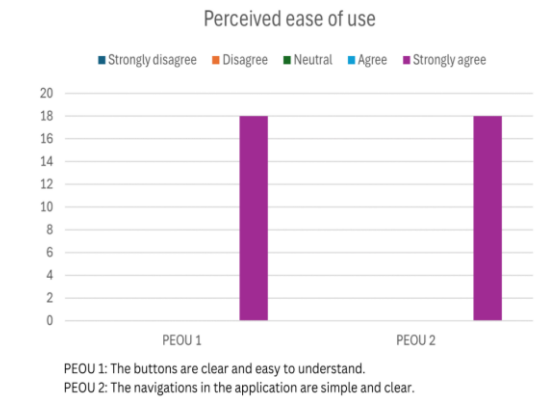


Fig. 7 Analysis perceived ease of use

Figure 7 shows all 18 respondents strongly agreed that all the buttons are clear and easy to understand and the navigations in the application are simple and clear. The six questions assess if the application is easy to use, informative, and engaging. They check if the buttons and navigation are clear, if the educational content is useful, AR and activities are effective, and if it improves learning compared to other methods. Overall, they aim to see how well the application helps users learn about food classes and keeps students interested.

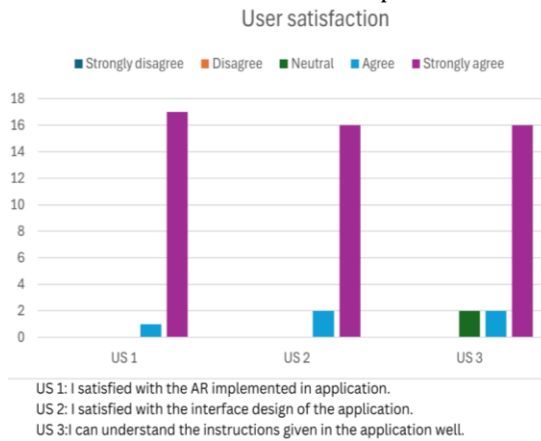


Fig. 8 Analysis user satisfaction

Figure 8 presents the analysis of user satisfaction (US) in relation to overall performance. The data set encompasses three questions. Question 1 reveals that 17 respondents expressed strong agreement with satisfied with the AR implemented in application, while only 1 respondent indicated agreement. In response to the second question satistion with the interface design of the application, 16 respondents indicated a strong agreement, while 2 respondents expressed agreement. 14 respondents strongly agreed, and 2 respondents agreed with the statement that thay can understand the instructions given in the application well while the remaining 2 respondents provided neutral responses. These results indicate that most respondents expressed strong agreement or agreement with the statements that they were satisfied with the application and that they did not encounter any issues.

The six questions evaluate whether the interface and navigation are clear, if the content is useful, the AR and activities are effective, and if users are happy with the AR, design, and instructions. Overall, they aim to see how well the app helps users learn about food classes and keeps them satisfied.

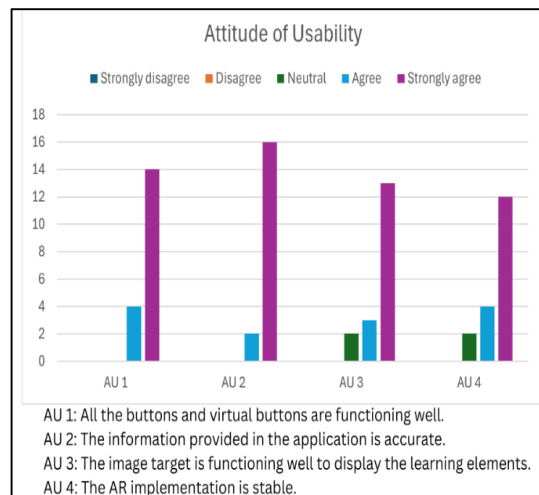


Fig. 9 Analysis attitude of usability

Figure 9 analyzes the usability attributes (UA) related to the application's functionality. It consists of four questions. Question 1 focused on how well buttons functioned. 14 respondents strongly agreed and 4 agreed that all buttons and virtual buttons worked well. Question 2 addressed the accuracy of information in the application. 16 respondents strongly agreed while 2 agreed that the information was accurate. Question 3 investigated how well the image target functioned for displaying learning elements. 13 respondents strongly agreed and 3 agreed that it functioned well. However, 2 respondents provided neutral responses. Question 4 examined the stability of the AR implementation. 12 respondents strongly agreed and four agreed that it was stable. 2 respondents provided neutral responses. In conclusion, the application received positive feedback in the aspects of perceive usability, perceive ease of use, user satisfaction and attitude of usability.

The six questions evaluate whether the app is easy to use, educational, and technically sound. They check whether the interface is clear, the content is useful, AR and activities are effective, buttons work, information is accurate, and AR is stable. Overall, they aim to see how well the app helps users learn about food classes and works reliably.

In conclusion, the application received positive feedback in the aspects of perceive usability, perceive ease of use, user satisfaction and attitude of usability.

5. Conclusion

The report begins by laying the foundation for the AR Nutri Food project, covering everything from the project's background to its objectives, scope, expected results, and significance. Following this, a comprehensive literature review is presented to establish the research base, including an analysis of existing applications in relation to the proposed AR application.

The chosen development methodology for the mobile learning application, Multimedia Mobile Content Development (MMCD), is then described. This is followed by a summary of the information discussed during the analysis and design phases of the project. The analysis phase involves investigating and defining the features and characteristics required to produce an effective application for the target users. During the design phase, a content structure, a navigation structure, and a flowchart are created to explain the process of creating the structure and components of the application.

The report then delves into the testing phase of the application, which includes both alpha and beta testing. Alpha testing is conducted by the developers to identify and fix any errors or bugs and to ensure that all elements of the application work correctly. Beta testing involves a group of target users assessing the usability and functionality of the application through their real-world experience.

The report concludes by examining the benefits and limitations of AR Nutri Food, analysing its success in achieving its objectives, and suggesting potential improvements for future development. In addressing the limitations of the study, the "AR NutriFood" application encounters challenges with inconsistent resolution on newer, higher-resolution Android devices, particularly with regard to height. Additionally, the lack of a database for storing user scores restricts the application's functionality. Future research directions include implementing a database to store module data, expanding AR features to encompass additional topics with detailed 3D models, resolving resolution issues across various Android devices, updating lesson content and game levels, and extending the application to iOS mobile and desktop platforms for enhanced accessibility and usability.

The advantages of AR Nutri Food, identified following the completion of the testing phase, include the usefulness of the information provided by the application, as it was found to have a positive effect on the perceived

usefulness (PU) of the information provided. However, a limitation is identified where there is no database involved for storing the users' scores in the application.

In conclusion, AR Nutri Food is suitable for children aged 9-12 to learn about food nutrition in their spare time. This application is designed as a guide for beginners, introducing a more interesting way of learning to the users instead of the traditional way of learning, which is interactive learning through an augmented reality approach. Apart from learning, the users are also allowed to play the games provided to enhance the learning interest of the users as well as to achieve the learning while playing mode.

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Conflict of Interest

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

Author Contribution

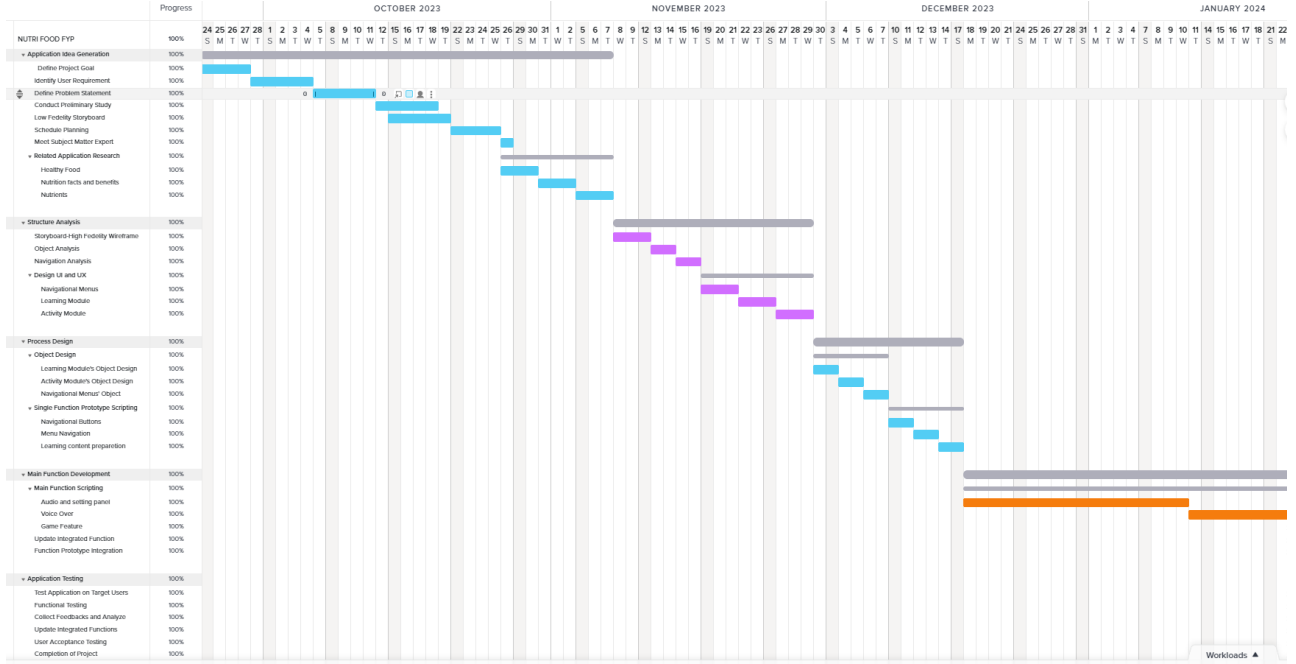
This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Tan Sze Jee, Dr Che Samihah binti Che Dalim; **data collection:** Tan Sze Jee, Dr Che Samihah Binti Che Dalim; **analysis and interpretation of results:** Tan Sze Jee, Dr Che Samihah Binti Che Dalim; **draft manuscript preparation:** Tan Sze Jee, Dr Che Samihah Binti Che Dalim. All authors reviewed the results and approved the final version of the manuscript.*

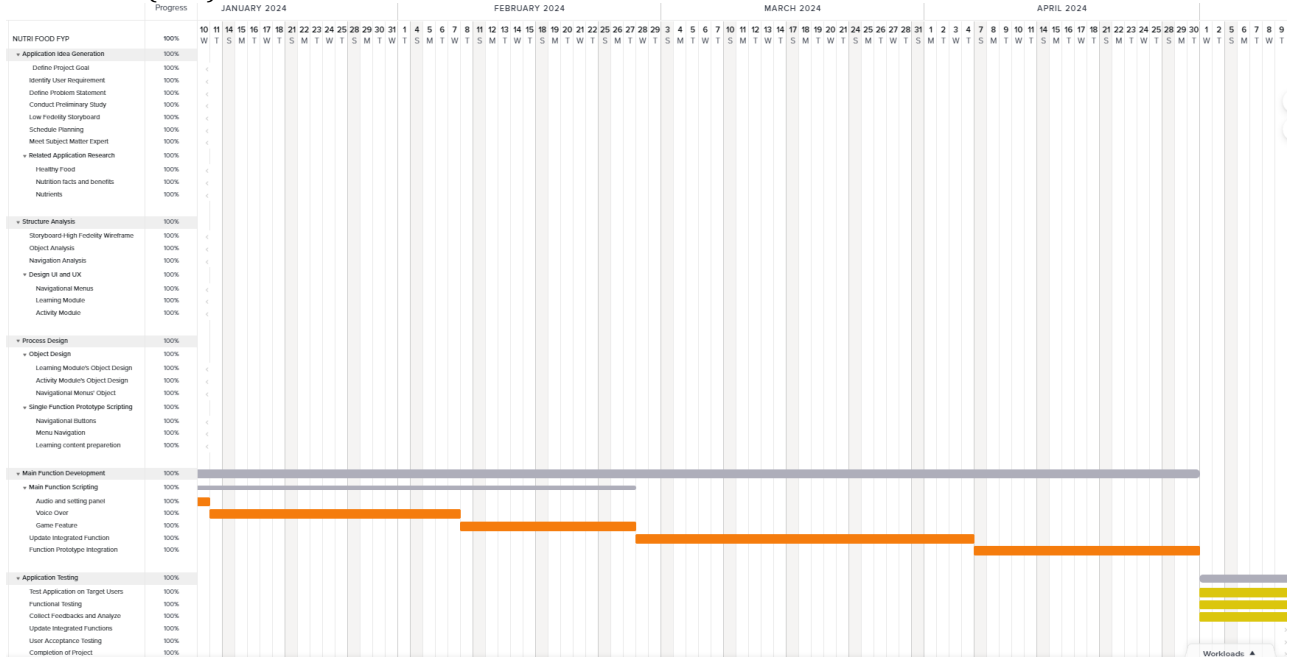
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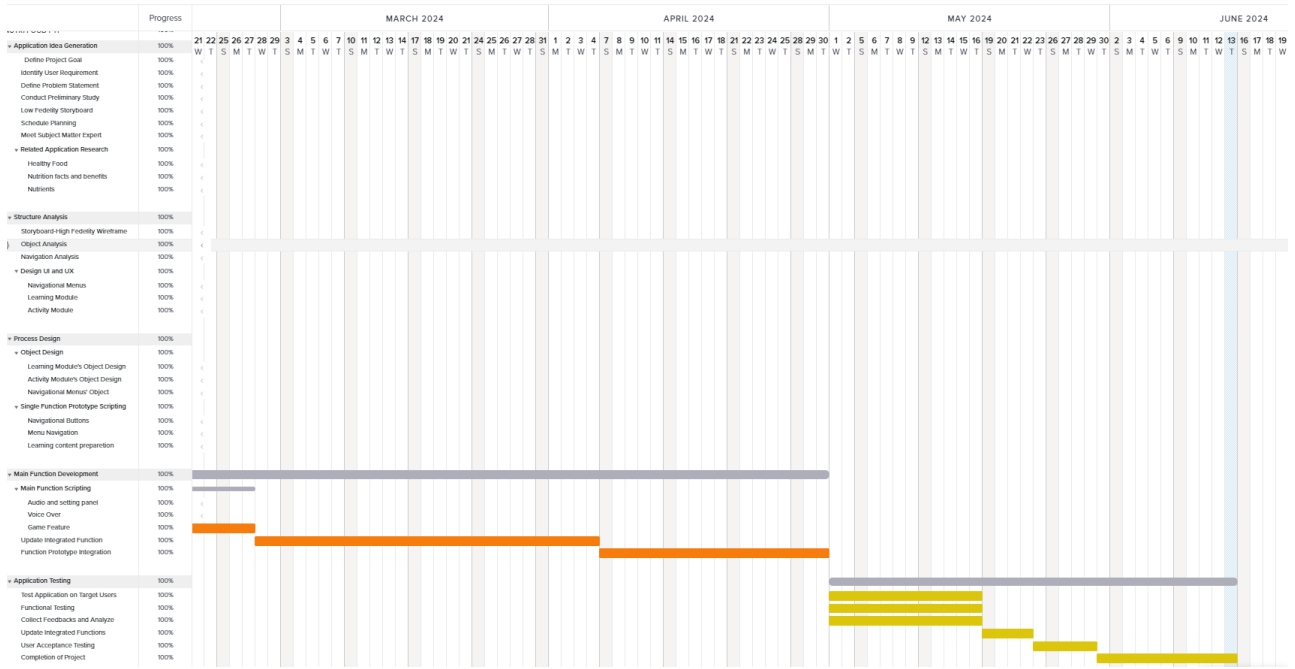
Appendix Gantt chart



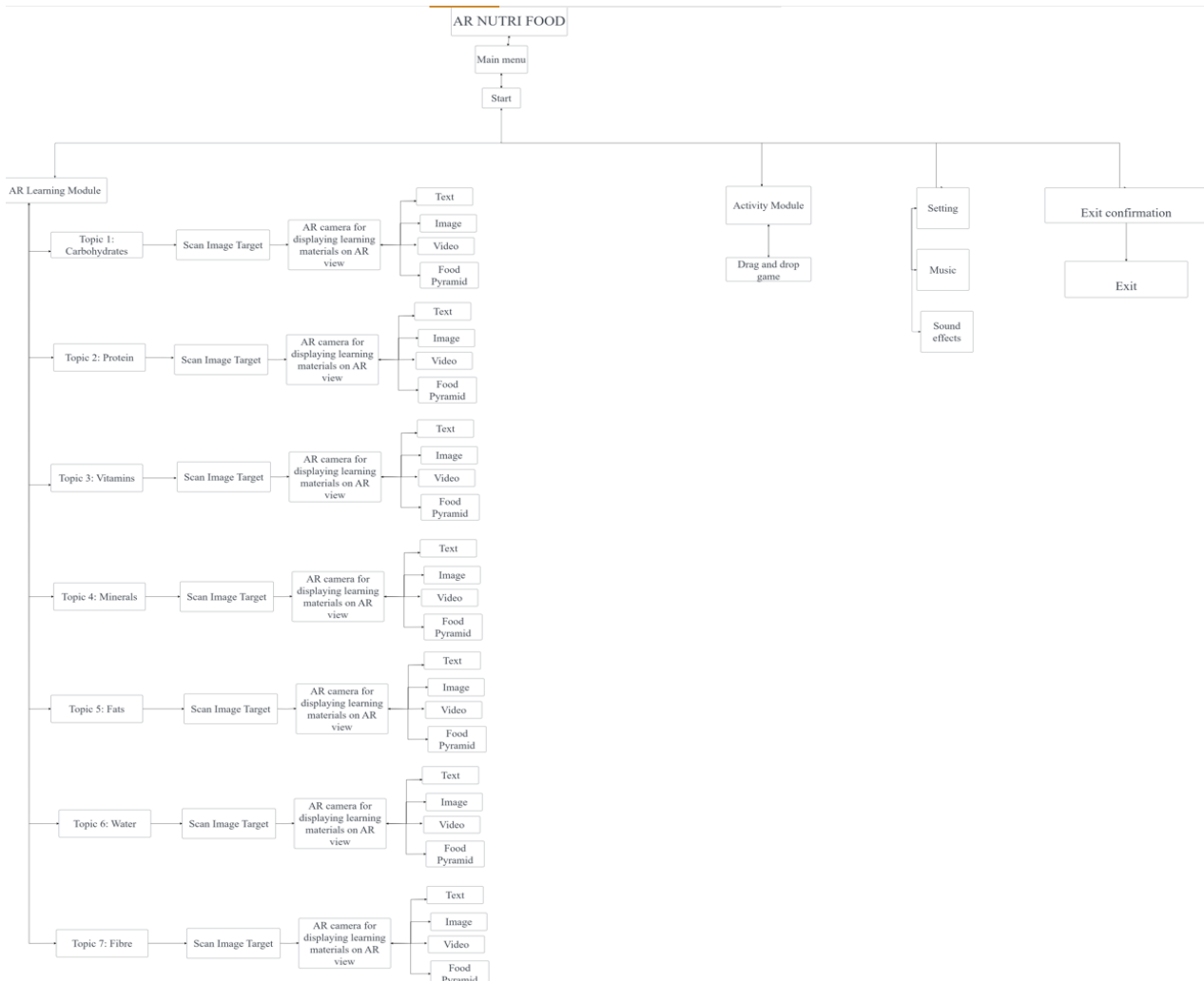
Gantt chart: (cont)



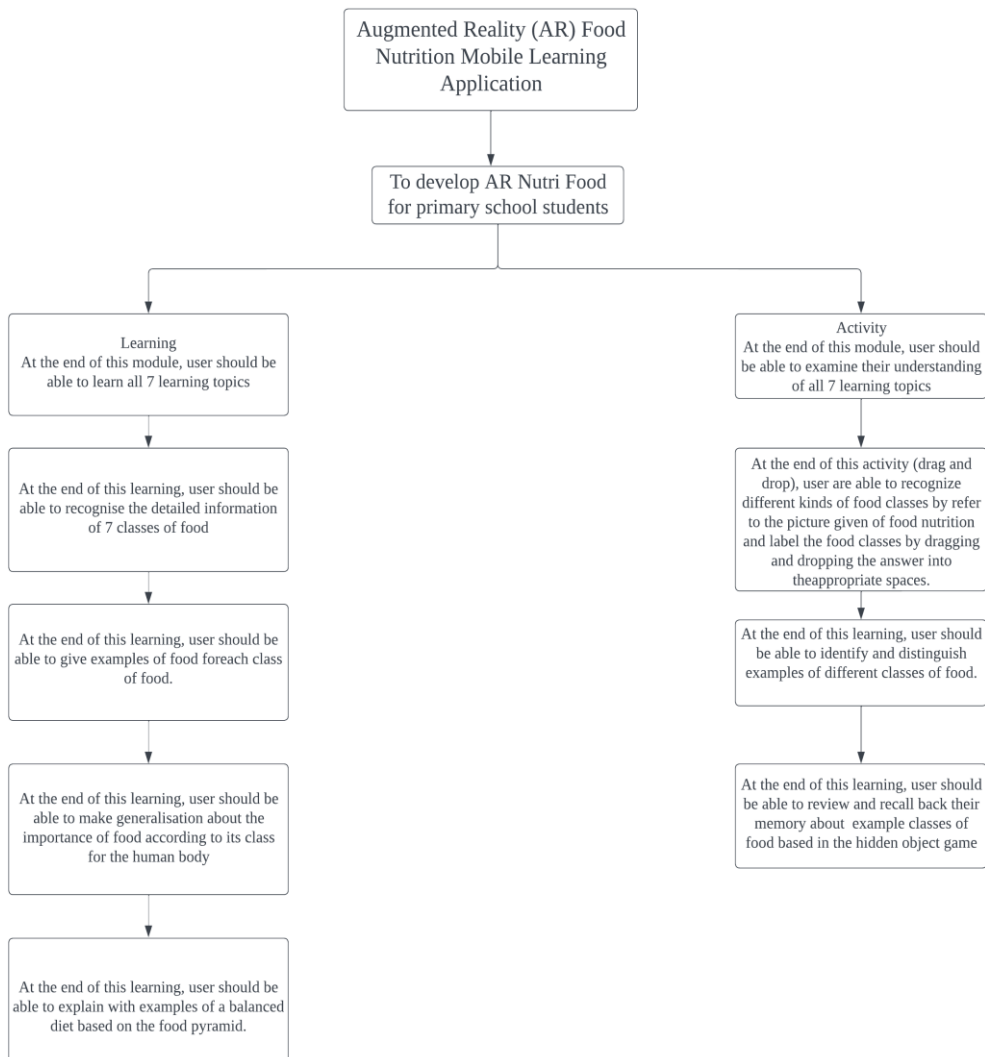
Gantt chart: (cont)



Navigation structure



Content structure



AR makers of classes of food

AR marker	Food Class	AR marker	Food Class	AR marker	Food Class	AR marker	Food Class
	Protein		Vitamins		Fats		Fibre
	Carbohydrates		Minerals		Water		

Photo of User Acceptance Testing



User testing questionnaire
Section 1: Perceived usefulness

Perceived usefulness (PU)

Linear Scale
1=Strongly Disagree
2=Disagree
3=Neutral
4=Agree
5=Strongly Agree

Linear Scale
1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

I found the learning information about the food classes in application is useful.

1 2 3 4 5

Strongly Disagree Strongly Agree

I can recognize the classes of food when after using the application.

1 2 3 4 5

Strongly Disagree Strongly Agree

Section 1: (cont)

I found that the AR session in the application can give me a clearer image about food classes./Saya mendapati bahawa sesi AR dalam aplikasi dapat memberi saya gambaran yang lebih jelas mengenai kelas makanan.

1 2 3 4 5

Strongly Disagree Strongly Agree

I get more information about the classes of food after playing the activity module./Saya mendapat lebih banyak maklumat mengenai kelas makanan selepas memainkan modul aktiviti.

1 2 3 4 5

Strongly Disagree Strongly Agree

I can learn better if use this application./Saya boleh belajar dengan lebih baik jika menggunakan aplikasi ini.

1 2 3 4 5

Strongly Disagree Strongly Agree

This application provide more interesting learning experience./Aplikasi ini menyediakan pengalaman pembelajaran yang lebih menarik.

1 2 3 4 5

Strongly Disagree Strongly Agree