

# Development of Game-Based Mobile Learning Application: Run for Health

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DOI: <https://doi.org/10.30880/aitcs.2024.05.02.040>

## Article Info

Received: 15 July 2024

Accepted: 16 October 2024

Available online: 15 December 2024

## Keywords

Mobile Learning Application,  
Nutrition, Game-based Learning

## Abstract

Understanding nutrition is vital for informed dietary decisions. However, the current approach to nutrition education faces challenges like inconsistency, misinformation, and undue emphasis on personal responsibility, adversely affecting individuals and society. To address these issues, this study developed "Run for Health," an interactive mobile application for children aged 7 to 12 to learn about nutrition during their leisure time. Nutritional apps are key to promoting healthier lifestyles, but they face challenges in user interface and experience design. This project aimed to fill a gap in the 2D platformer genre on the Google Play Store by developing the game on Android using Unity. The app's functionality and user acceptance were tested on the target audience at Sekolah Kebangsaan Pintas Raya. The average SUS score was 79.375, which is higher than 68 indicate that "Run for Health" was well-received by its target users, achieving the project's objectives successfully.

## 1. Introduction

Nutrition is fundamentally a science. It is premised on an understanding of human physiology and biochemistry and the action of nutrients and other food constituents [1]. The foods we eat provide our bodies with the nutrients we need to function properly. These nutrients include protein, carbohydrates, fats, vitamins, minerals, and water. Each nutrient plays a specific role in supporting our health. For example, protein is essential for building and repairing muscle tissue, carbohydrates provide energy, and fats help to insulate our bodies and support hormone production. When we don't get enough of the nutrients we need, or when we get too much of specific nutrients, it might cause health concerns. A shortage of protein, for example, can lead to muscle loss and weakness, but an excess of fat can lead to obesity and heart disease. One of the most important things we can do for our health is to eat a nutritious diet. A healthy diet provides our bodies with all the nutrients they require in the appropriate amounts. This can aid in the maintenance of a healthy weight, the prevention of chronic diseases, and the promotion of overall health [2].

Nutritional knowledge is crucial since it allows us to make informed eating choices. We can ensure that we are getting the nutrients we need and avoiding the nutrients we don't need by understanding what nutrients are in the foods we eat and what they do for our bodies. In schools, nutrition is often taught as part of a health education curriculum. Schools may also use a variety of technology to teach nutrition, such as interactive whiteboards, tablets, and laptops. Students may learn about nutrition through online lessons, games, and simulations. While outside of school, social media is playing an increasingly important role in nutrition education. Many registered dietitians and other nutrition experts share nutrition information and recipes on social media platforms such as Instagram and TikTok.

Nowadays, the current practice of teaching about nutrition has several problems, including a lack of consistency, misinformation, and focus on individual blame [3]. The problems in current nutrition education can have several negative implications for individuals and society. For individuals, lack of access to nutrition education and misinformation can lead to poor dietary choices and increased risk of chronic diseases. For society, the cost of obesity and other chronic diseases is a major economic burden. However, several things can be done to improve nutrition education, including developing and implementing consistent nutrition standards, making nutrition education more accessible, and shifting the focus to promoting positive health behaviors [4].

Therefore, nutritional applications play a crucial role in our modern quest for healthier living, yet they are not immune to certain challenges. Nowadays, 2D and 3D game-based applications are being widely used to deliver educational content. However, a noticeable gap exists in the 2D platformer category of nutritional games on the Google Play Store, which consequently leads to deficiencies in user interface and user experience design.

This study aims to design and develop 'Run for Health', an interactive mobile learning application utilizing a game-based approach, specifically tailored for Android technology. The application targets children aged 7 to 12, aiming to enhance their learning experience. Alpha testing will be conducted to evaluate the application's functionality and usability. Cikgu Siti Suhaidah bt Mohd Jalil, a Science teacher at Sekolah Kebangsaan Pintas Raya in Parit Raja, Johor, will provide her expertise as the Subject Matter Expert (SME) for this project.

The remainder of the paper is structured 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 result and discussion of the current progress, followed by conclusion in Section 5.

## 2. Related Work

This section explains the study domain, the technology applied, and the comparative analysis results.

### 2.1 Nutrition Learning

Nutrition learning involves acquiring knowledge and understanding of the principles, concepts, and practices related to nutrition. It is the process by which individuals gain insights into the role of food and nutrients in promoting health, preventing diseases, and maintaining overall well-being. Nutrition education aims to empower individuals to make informed and healthy food choices for themselves and their communities. The children are a productive age group who needs an adequate nutritional intake to ensure their productivity in their studies daily. A long-term period of unbalanced nutrition consumption might impact one's health and productivity. One of the interventions that can be done is through education to increase their knowledge of balanced nutrition.

Nutritious foods defined as a food that in the context where it is consumed and by the individual that consumes it, provides beneficial nutrients and minimizes potentially harmful elements. Nutrition education is often integrated into school curricula at various levels, teaching students the basics of nutrition and promoting healthy eating habits [5]. With the rise of technology, mobile applications and online platforms offer interactive and accessible ways for individuals to learn about nutrition at their own pace. Therefore, nutrition learning provides individuals with the knowledge and skills needed to make informed and healthy food choices, ultimately contributing to overall well-being and a healthier lifestyle.

In conclusion, nutrition learning is a lifelong process that contributes to individual and community well-being. It empowers individuals to make informed choices that positively impact their health and quality of life.

### 2.2 Interactive Technology

Interactive technology has been defined as methods, tools, or devices that users interact with in order to achieve specific tasks [6]. This means that interactive technology can function based on user input and generate a response accordingly, serving a wide range of purposes such as education, entertainment, communication, and commerce.

A range of studies have explored the use of game-based interactive technology in various contexts. Hwang [7] and Boiano [8] both highlight the effectiveness of game-based learning in language acquisition and the evolution of computer-based museum interactives and games, respectively. Pillai [9] and Dyulicheva [10] delve into the potential of game-based technology in rehabilitation and education, with Pillai focusing on a virtual reality-assisted gaming system for hand rehabilitation and Dyulicheva discussing the development of serious educational games with artificial intelligence and immersive technologies. These studies collectively underscore the potential of game-based interactive technology in enhancing learning, rehabilitation, and cultural experiences.

Therefore, interactive technology offers several advantages over traditional non-interactive technology. Firstly, it engages and motivates users by allowing them to interact with it, thus increasing their attention and learning rate. Secondly, interactive technology can be customized to meet the requirements and interests of each user, resulting in a more personalized experience. Finally, interactive technology can foster collaboration among users. Interactive technology enables individuals to engage with each other, promoting the exchange of ideas,

collaboration on projects, and mutual learning. As a result, mobile technology can influence the learning process through interactions with applications, according to research by Bernacki et al. [11]. Thus, the children can expose to nutrition education via mobile technology throughout the application.

## 2.3 Comparative Analysis

In this section, a comparison table has been created to compare the three existing application for children to learn nutritional knowledge, which are “Start Simple with MyPlate”, “Fooducate: Nutrition Coach”, and “MyFitnessPal”, with the proposed application for this project, “Run for Health”. Overall, “Run for Health” is going to include all the strengths of the existing applications while overcoming their weaknesses. The comparison is based on various features, as displayed in the Table 1 below.

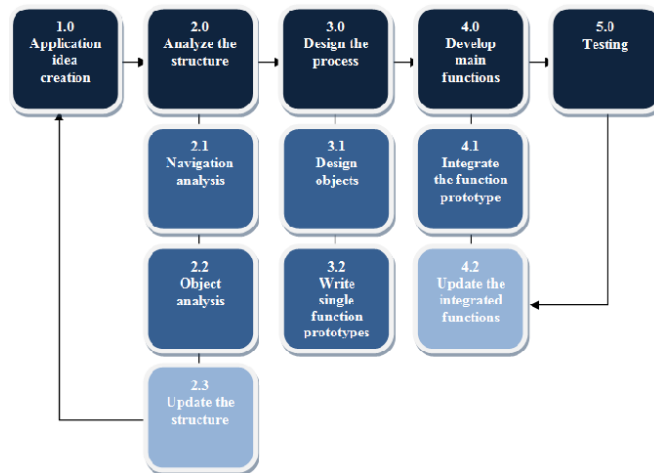
**Table 1** Comparison between the existing nutrition learning mobile applications

Applications	Start Simple with MyPlate	Fooducate: Nutrition Coach	MyFitnessPal	Run For Health
Platform	Android 4.0.3 or above	Requires iOS 13.0 or later.	Android 4.0.3 or above	Android 4.0.3 or above
Pricing	Free	Free, but contains in-App purchase to unlock the external features.	Free, but contains in-App purchase to unlock the external features.	Free
Number of modules	1	1	1	2
Learning Module	Available	Available	Available	Available
Game Content	Not available	Not available	Not available	Available
Background Music	Not available	Not available	Not available	Available
Setting Panel	Not available	Available	Available	Available
Learning Content Selection Interface	Not available	Not available	Not available	Available
Learning Content Interface	Available	Available	Available	Available
Design Theme	Colorful	Colorful	Colorful	Colorful
Advertisement	Not Include	Not Include	Not Include	Not Include

## 3. Methodology

Multimedia Mobile Content Development (MMCD) [12] is one of the development methodologies that is suitable for developing a mobile learning application. There are a total of five stages, which are the application idea creation stage, analyze the structure stage, design the process stage, develop main functions stage and testing stage in the MMCD methodology as shown in Figure 1, alongside with their respective substages. This project

carried out all the stages of MMCD except for the update the status phase. This phase is omitted due to time constraint.



**Fig. 1** Stages of Multimedia Mobile Content Development (MMCD)

### 3.1 Application Idea Creation Phase

The initial phase of the MMCD methodology involves the creation of application ideas. This is the first stage in which the application’s concept is developed. At this stage, the project developer must compile the necessary information required for the application’s development before commencing with the actual design and development process. A checklist for application idea creation has been produced and is presented in Table 2.

To identify user requirements, an interview session had been carried out with Cikgu Siti Suhaidah bt Mohd Jalil, a Science subject teacher in Sekolah Kebangsaan Pintas Raya, Parit Raja, Johor. She is the Subject Matter Expert for this project and the interview session is conducted through physical meeting. The interview questions with the SME are provided in Appendix A. A completed user analysis is tabulated in Table 3 as follow according to analysis based on the interview.

**Table 2** Application Idea Creation Check List

Item	Note
Type of application	Game-based Learning application
Platform	Android mobile
Target users	7 to 12 years old children
Graphical User Interface	Main interface, gamified learning module interface, game module interface and module selection interface.
Image	Graphic for nutrition learning and button icons.
Animation	Setting interface, animated background, score animation, pause interface, food pyramid video interface, and reward interface.
Audio	Background music and voice-over sound.
Application summary	Run For Health is a mobile application designed to teach nutrition to children between the ages of 7 and 12, utilizing a 2D game-based approach. Its objective is to provide an interactive platform for children to gain knowledge about nutrition.

**Table 3** *User analysis of Run for Health*

Stakeholder Category	Role in Application	Design Implication	Action Needed
Subject Matter Expect	Consultant expert on content in related field	Simple while colorful user interface	<ul style="list-style-type: none"> <li>Prevent complicated design on interface while offering some colorful element to draw children attention.</li> <li>The mapping of objects on interface should be simple to prevent children from confusion.</li> </ul>
		Easy to navigate between interfaces	<ul style="list-style-type: none"> <li>Navigational and functional buttons provided should be as many as possible.</li> <li>Use icon-based buttons instead of text-based for better understanding on function of buttons.</li> <li>Navigational structure of application should be simple.</li> </ul>
		Children-friendly learning	<ul style="list-style-type: none"> <li>Use simple word and graphic for learning module.</li> <li>Use simple English as instruction.</li> </ul>
		Offline feature	<ul style="list-style-type: none"> <li>The application should be able to access at anywhere, anytime on mobile device.</li> </ul>
		Simple but reliable content	<ul style="list-style-type: none"> <li>Include nutritional knowledge that are suitable for 7 to 12 years old children.</li> <li>Avoid complicated words.</li> <li>May refer to Year 1 to Year 6 Science syllabus.</li> </ul>

### 3.2 Analyze the Structure Phase

The structure of the application to be created is studied in the second stage of the MMCD method. The object and navigation analysis are performed. The navigation structure is illustrated in Figure 2 while Figure 3 displays the main system flowcharts. Meanwhile, Appendix B contains the hierarchical task analysis and content structure for the modules. Appendix C has a breakdown of the flowcharts. Tables 4 and Table 5 list the functional and non-functional criteria.

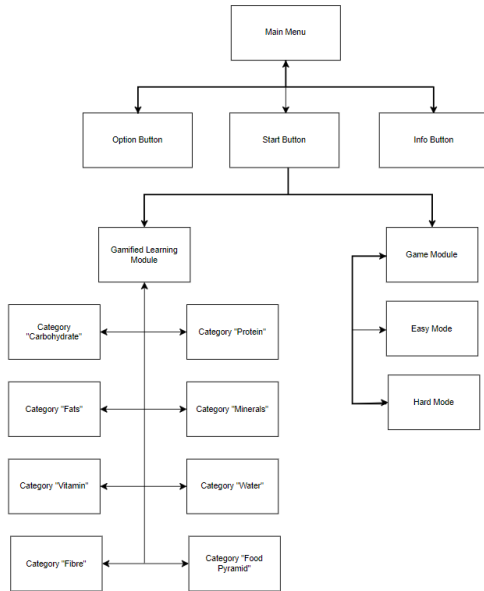


Fig. 2 Navigation structure

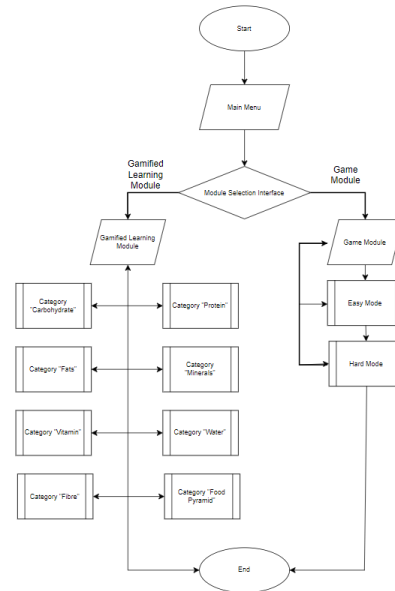


Fig. 3 Main system flowchart

Table 4 Functional requirements

Functional Requirement	Explanation
Supportive for User Interaction	<ul style="list-style-type: none"> <li>The application should enable users to inputs by interacting with the touch screen of their mobile devices.</li> <li>The application should provide users with the ability to navigate between different interfaces using appropriate navigational buttons.</li> <li>The application shall provide an “Next” button to navigate every interface.</li> <li>The application shall provide a “Return” button for users to quit to the previous interface.</li> <li>The application shall provide a “Music” button which acts as an on/off switch for the background music of the application.</li> <li>The application shall provide a “Voice-Over” button which acts as a voice-over sound to help users to read the text.</li> </ul>
Provide Learning Module	<ul style="list-style-type: none"> <li>The application should allow users to recognize the functions and benefits that is related to the nutrition.</li> <li>The application should allow users to understand the important of the daily nutrition for the human body.</li> <li>The application should help stimulate children’s interest as well as motivate them in learning Science, more specifically in food and nutrition from an early age.</li> </ul>

**Table 4** *Functional requirements (cont.)*

Functional Requirement	Explanation
Game Module	<ul style="list-style-type: none"> <li>While the game is carrying out, the application should be able to calculate the healthy foods achieved every time they get the healthy food.</li> <li>If users get all the healthy food and pass all the obstacles and unhealthy foods, they will be navigated to the game complete panel.</li> <li>If users failed pass all the obstacles and unhealthy foods, they will be navigated to the trivia game over panel.</li> <li>The background music shall be played automatically once click into the application.</li> <li>The "Pause" button shall be clicked when users need to pause the game.</li> </ul>





**Table 5** *Non-functional requirements*

Non-functional Requirement	Explanation
Performance	<ul style="list-style-type: none"> <li>This application shall be able to access anytime.</li> </ul>
Implementation	<ul style="list-style-type: none"> <li>This application shall be applied as an offline-based interactive application.</li> </ul>
Legal	<ul style="list-style-type: none"> <li>This interactive application shall be able to operate by using any Android-based mobile platform except iOS-based mobile system.</li> </ul>
Culture	<ul style="list-style-type: none"> <li>Users should be able to use this application easily, learn the nutritional knowledge effectively, and gain satisfying user experience when using this application.</li> </ul>
Graphical User Interface Support	<ul style="list-style-type: none"> <li>There are many statistical facts about nutrition such as carbohydrates, fiber, protein, and others that shall be provided based on Malaysia statistics instead of world-wide statistics.</li> <li>The application should support all essential elements, including graphics, animations, audio, and text for different sizes of display resolution on Android mobile.</li> </ul>





















### 3.3 Design the Process Phase

According to the third phase of the Multimedia Content Development (MMCD) methodology, one of the sub-phases that the application developer has to go through is the design of objects. In this case, the objects required by the proposed application, Run for Health, such as the navigation buttons and the interfaces, are listed and explained in detail. Authoring tools such as Adobe Photoshop is applied in this project to generate pictures and storyboard. Meanwhile, Unity software is utilized to develop the scripting assets. The C# scripts are also created to enable the application's key features. Table 6 illustrates the button design, while Table 7 displays all the interface designs.



**Table 6** *Button design*

Button	Explanation	Button	Explanation
	This is a Start Button which located at main menu interface.		This is a Close Button.
	This is an Option Button which located at main menu interface.		This is a Home Button.







**Table 6** *Button design (cont.)*

Button	Explanation	Button	Explanation
	This is an Exit Button which located at setting interface.		This is a Learning Button which located at module selection interface.
	This is a Background Music-On Button which located at the setting panel.		This is a Game Button which located at module selection interface.
	This is a Background Music-Off Button which located at the setting panel.		This is the Pause Button.
	This is the Info Button.		This is the Return Button.
	This is the Carbohydrates Button which can view the information about carbohydrates.		This is the Next Button.
	This is the Protein Button which can view the information about protein.		This is the Vitamins Button which can view the information about vitamins.
	This is the Fats Button which can view the information about fats.		This is the Minerals Button which can view the information about minerals.
	This is the Fiber Button which can view the information about fiber.		This is the Water Button which can view the information about water.
	This is the Reading Sound Button which located at every nutrition stage.		This is the Food Pyramid Button which can view the information and video about food pyramid.
	This is the Resume Button which located at Game module when the pause button was clicked.		This is the Left Button which located at Game module to control the character move to the left.
	This is the Restart Button which located at Game module when the pause button was clicked.		This is the Right Button which located at Game module to control the character move to the right.

**Table 6** Button design (cont.)

Button	Explanation	Button	Explanation
	This is the Exit Button which located at Game module when the pause button was clicked.		This is the Jump Button which located at Game module to control the character to jump.


**Table 7** Interface design

Interfaces	Description
	This is the startup interface and also main menu of the proposed application. The user can click the Play button to the module selection, Setting button to the setting interface and Info button to the information interface.
	This is the setting interface which contains on-off button of background music, home button and quit button.
	This is the information interface that notifies users of the name of each type of icon and button.
	This is the module selection of this proposed application. The user clicks the play button in the learning module will go to learning module while the play button in the game module will go to game module.
	This is the unlock type learning module. The user needs to read through all the nutrition stage from first to the end to unlock all the nutrition stage. The food pyramid icon will navigate user to food pyramid interface while the Cancel button will navigate user back to module selection interface.
	This is the game module when clicked after game module in the module selection interface. When the play button clicked, it will navigate user to the game interface to play the game.

### 3.4 Develop Main Function Phase

This phase will focus on developing the main functions of the proposed application. The key features of the proposed application are established during this phase. It requires the construction of application assets, the integration of these assets into the application, and the integration of application assets. Table 8 summarizes its components, which include audio and graphics while the completed interface design will show in the appendix D.

**Table 8** Application assets development

Assets	Development	Description
Audio		The audio files within the Run For Health application employ the Moving Picture Experts Group Layer-3 Audio (MP3) format, meticulously recorded by the author to guarantee the preservation of copyright protection.
Graphics		Adobe Photoshop is used to edit the components like buttons, photos, and application icons, while their backgrounds or illustrations are transparent.

The C# scripts are also created to enable the application's key features. Implementing a sceneries switcher, PlayerMovements, PlayerLife, CameraController, PauseMenu and ItemCollector are some examples of such functionalities. In Table 9, those actions are described. The created application's interfaces are shown in appendix D in the meanwhile.

**Table 9** Integration C# in Unity

Functions	C# Scripts	Description
Player Movement	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine;  public class PlayerMovement : MonoBehaviour {     private BoxCollider2D coll;     private SpriteRenderer sprite;     private Animator anim;     private enum MovementState { idle, running, jumping, falling }      [SerializeField] private LayerMask jumpableGround;     [SerializeField] private AudioSource jumpSoundEffect;      PlayerControls controls;      float direction = 0;     public float speed = 400;      public float jumpForce = 8;      public Rigidbody2D rb;      private void Start()     {         rb = GetComponent&lt;Rigidbody2D&gt;();         coll = GetComponent&lt;BoxCollider2D&gt;();         sprite = GetComponent&lt;SpriteRenderer&gt;();         anim = GetComponent&lt;Animator&gt;();     }      private void Awake()     {         controls = new PlayerControls();         controls.Enable();          controls.Land.Move.performed += ctx =&gt;         {             direction = ctx.ReadValue&lt;float&gt;();         }     } }                     </pre> <pre> MovementState state;  if (direction &gt; 0f) {     state = MovementState.running;     sprite.flipX = false; } else if (direction &lt; 0f) {     state = MovementState.running;     sprite.flipX = true; } else {     state = MovementState.idle; }  if (rb.velocity.y &gt; .1f) {     state = MovementState.jumping; } else if (rb.velocity.y &lt; -.1f) {     state = MovementState.falling; }  anim.SetInteger("state", (int)state); }  void Jump() {     if (IsGrounded())     {         jumpSoundEffect.Play();         rb.velocity = new Vector2(rb.velocity.x, jumpForce);     } }                     </pre>	The "PlayerMovement" script in Unity handles the player's movement, jumping, and animation state updates.
Camera Controller	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine;  public class CameraController : MonoBehaviour {     [SerializeField] private Transform player;     private void Update()     {         transform.position = new Vector3(player.position.x, player.position.y, transform.position.z);     } }                     </pre>	This script ensures that as the player moves, the camera follows, keeping the player centered in the view. It is suitable for many 2D platformer or side-scrolling games.

Table 9 Integration C# in Unity (cont.)

Functions	C# Scripts	Description
PauseMenu	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine; using UnityEngine.SceneManagement;  public class PauseMenu : MonoBehaviour {     [SerializeField] GameObject pauseMenu;      public void Pause()     {         pauseMenu.SetActive(true);         Time.timeScale = 0; // Freeze the game     }      public void Home()     {         SceneManager.LoadSceneAsync(1);         Time.timeScale = 1; // Unfreeze the game     }      public void Resume()     {         pauseMenu.SetActive(false);         Time.timeScale = 1; // Unfreeze the game     }      public void Restart()     {         SceneManager.LoadScene(SceneManager.GetActiveScene().buildIndex);         Time.timeScale = 1; // Unfreeze the game     } } </pre>	<p>This script ensures that the game can be paused, resumed, navigated back to the home menu, or restarted, all while managing the game's time scale to freeze and unfreeze the game appropriately.</p>
Player_Life	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine; using UnityEngine.SceneManagement;  public class Player_Life : MonoBehaviour {     private Rigidbody2D rb;     private Animator anim;      [SerializeField] private AudioSource deathSoundEffect;      private void Start()     {         rb = GetComponent&lt;Rigidbody2D&gt;();         anim = GetComponent&lt;Animator&gt;();     }      private void OnCollisionEnter2D(Collision2D collision)     {         if (collision.gameObject.CompareTag("Trap"))         {             Die();         }     }      private void Die()     {         deathSoundEffect.Play();         rb.bodyType = RigidbodyType2D.Static;         anim.SetTrigger("death");     }      private void RestartLevel()     {         SceneManager.LoadScene(SceneManager.GetActiveScene().name);     } } </pre>	<p>The "Player_Life" script in Unity ensures that when the player hits an obstacle, they hear a sound, stop moving, see a death animation, and can restart the level when hits the obstacles and unhealthy foods.</p>
Sceneries switcher	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine; using UnityEngine.SceneManagement; using UnityEngine.UI;  public class MainMenu : MonoBehaviour {     public void PlayGame()     {         SceneManager.LoadSceneAsync(1);     } } </pre>	<p>This script is typically attached to a GameObject in the main menu scene, and the "PlayGame" method is assigned to a UI button's onClick event to transition from the main menu to the gameplay scene when the button is pressed.</p>
Item Collector	<pre> using System.Collections; using System.Collections.Generic; using UnityEngine; using UnityEngine.UI;  public class NewBehaviourScript : MonoBehaviour {     private int apples = 0;      [SerializeField] private Text applesText;      [SerializeField] private AudioSource collectionSoundEffect;      private void OnTriggerEnter2D(Collider2D collision)     {         if (collision.gameObject.CompareTag("Apple"))         {             collectionSoundEffect.Play();             Destroy(collision.gameObject);             apples++;             applesText.text = apples + " / 15";         }     } } </pre>	<p>This script provides a simple yet effective way to handle the collection of items in a game, enhancing the player's experience with both visual and audio feedback. It can be expanded by adding more features such as different types of collectibles or additional UI elements.</p>

### 3.5 Testing Phase

The testing phase is the final stage of the MMCD development methodology. In this section, the testing phase that is carried out on the proposed application, Run for Health will be discussed. In order to make sure that all the functions of the application work fine, alpha testing and beta testing were carried out to achieve the mentioned purpose. The alpha testing was done by the application developer throughout the development process of the application until the project is completed whereas the beta testing was carried by involving the target users of the application after the project is completed.

## 4. Results and Discussion

### 4.1 Alpha Testing

Table 10 shows the results of Alpha testing on the main buttons.

**Table 10** *Functional Testing*

Test	Expected Result	Actual Result	Corrective Action
Home button	Navigate to the home page	Works well as planned.	Not needed
Back button	Navigate to the previous page	Works well as planned.	Not needed
Audio button	Play the audio	Works well as planned.	Not needed
Close button	Close the panel	Works well as planned.	Not needed
Player's movement button	Control in-game character to move left, right and jump	Works well as planned.	Not needed
Life system	Track the player's life and restart the level when hits the obstacles and unhealthy foods.	Works well as planned.	Not needed
Module Selection button	Navigate either to learning module or game module	Works well as planned.	Not needed

From the results of the functional testing are shown in Table 10, it summarizes the results of various functional tests conducted on different features or buttons within an application. The buttons in Run for Health functioned as expected during the functional testing phase. No corrective actions are needed for any of the features listed, as they all performed according to the planned expectations. This suggests that the functionalities tested are implemented correctly and are functioning well within the application.

### 4.2 Beta Testing

In this section presents statistics and analysis obtained from user acceptance test. The purpose of the test was to assess the level of acceptance among users towards the developed application. In this scenario, a set of questions was displayed on Google Form and delivered alongside the application's APK file to the target users.

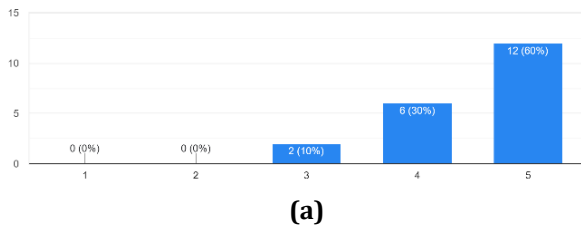
This study investigates the usability and user acceptance of the developed application. To measure the usability, a group of 20 students from Sekolah Kebangsaan Pintas Raya and a set of SUS-based questionnaires were distributed and analyzed. In addition, two questions were asked for confirmation on the technology acceptance which stated in the Appendix E. The questions asked are as below Figure 4 and Figure 5 shown. Table 11 displays the collected data after the SUS-based questionnaires calculation while Figure 4 and Figure 5 display the bar charts of the data after SUS-based questionnaires.

**Table 11** A set of collected data after beta testing in Sekolah Kebangsaan Pintas Raya

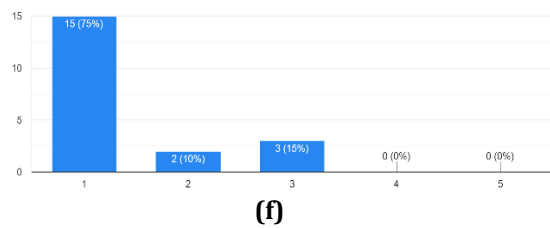
Username	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Score
R1	5	3	4	1	5	3	4	2	3	5	67.5
R2	5	1	5	4	5	1	5	2	5	4	82.5
R3	5	1	5	4	5	1	5	2	5	4	82.5
R4	5	1	5	5	5	1	5	1	5	5	80
R5	4	1	5	3	5	1	5	1	5	5	82.5
R6	5	2	5	3	5	2	5	1	4	5	77.5
R7	4	1	5	4	5	1	5	1	5	5	80
R8	3	2	4	1	5	3	4	2	4	5	67.5
R9	5	1	5	1	5	1	5	2	5	5	87.5
R10	3	1	4	2	5	1	5	3	5	5	75
R11	5	1	4	2	5	1	5	1	5	4	87.5
R12	4	2	3	3	5	1	4	2	4	5	67.5
R13	5	1	5	1	5	2	5	3	5	5	82.5
R14	5	2	4	2	5	1	5	1	5	5	82.5
R15	5	2	5	2	5	1	4	5	5	4	75
R16	5	1	5	2	5	2	4	5	5	5	72.5
R17	5	1	5	1	5	1	5	1	5	4	92.5
R18	4	2	4	2	5	1	5	1	5	5	80
R19	5	1	5	1	5	1	5	1	5	4	92.5
R20	5	2	4	2	5	1	5	3	3	5	72.5
Average:											79.375

The SUS survey assigns responses to a scale of points, allowing for a numerical representation of subjective user feedback. The scale is divided into odd-numbered and even-numbered questions for calculation purposes. The final SUS score is determined using a formula:  $SUS\ Score = x + y * 2.5$ , which combines the x and y values to get the system's perceived usability. The SUS score is presented as a percentage, ranging from 0 to 100. A perfect score of 100% signifies flawless usability and an exceptional user experience. The average SUS score is 68, with scores up to 70% generally considered good. A good sus score indicates a decent level of usability. Scores below 50% indicate low sus scores and a potential deficiency in usability, suggesting the need for substantial improvements to enhance user satisfaction. Based on the Table 11, the set of collected data after beta testing in Sekolah Kebangsaan Pintas Raya shows that the average SUS score was 79.375, which is higher than 68. Therefore, Run for Health mobile learning application signifies flawless usability and an exceptional user experience.

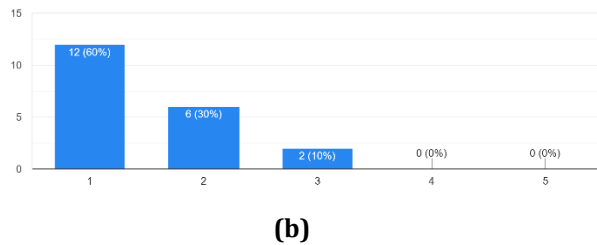
1. I think that I would like to use this application frequently. / Saya fikir saya ingin menggunakan aplikasi ini dengan kerap.  
20 則回應



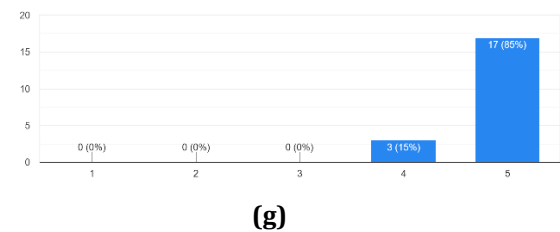
6. I thought there was too much inconsistency in this application. / Saya fikir terdapat terlalu banyak ketidaksesuaian dalam aplikasi ini.  
20 則回應



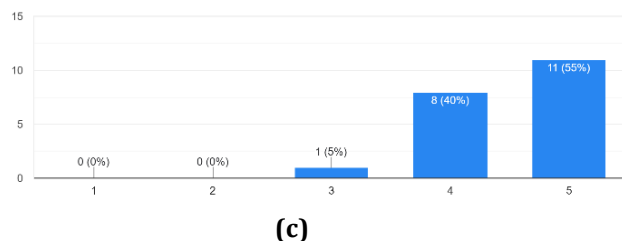
2. I found the application unnecessarily complex. / Saya mendapati aplikasi yang tidak perlu rumit.  
20 則回應



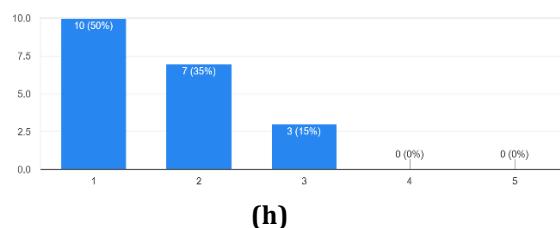
7. I would imagine that most people would learn to use this application very quickly. / Saya akan membayangkan bahawa kebanyakan orang akan belajar menggunakan aplikasi ini dengan sangat cepat.  
20 則回應



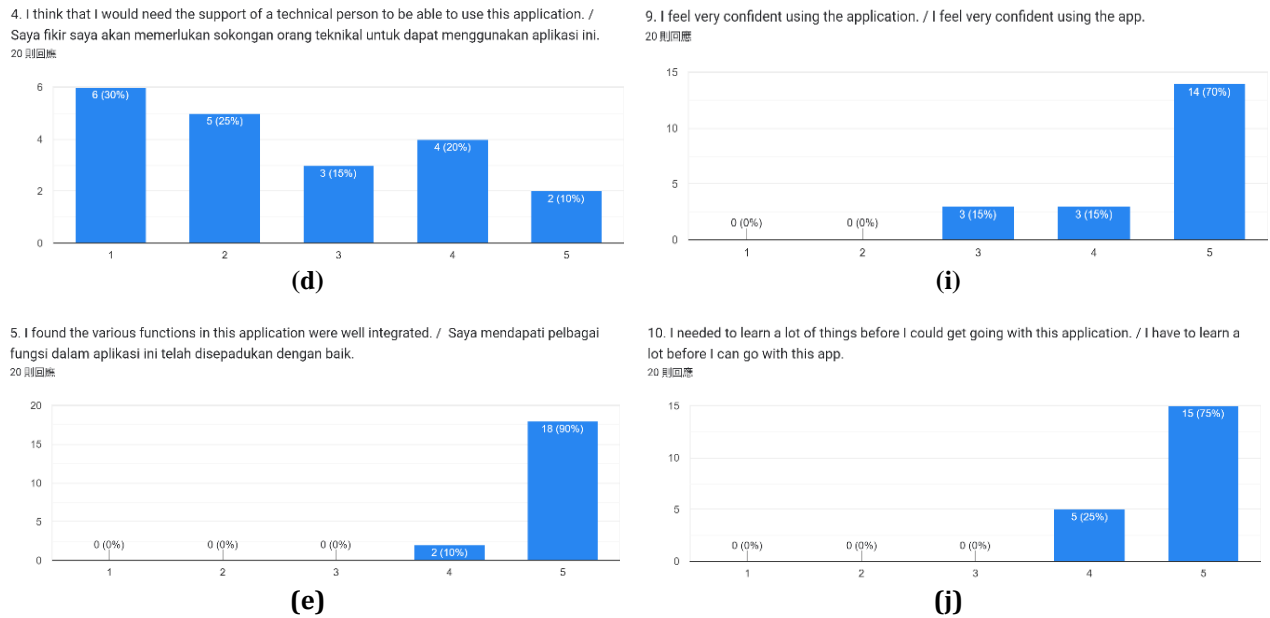
3. I thought the application was easy to use. / Saya fikir aplikasi itu mudah untuk digunakan.  
20 則回應



8. I found the application very cumbersome to use. / Saya mendapati aplikasi ini sangat sukar untuk digunakan.  
20 則回應



**Fig. 4** Figure description (a) Question 1; (b) Question 2; (c) Question 3; (f) Question 6; (g) Question 7; (h) Question 8



**Fig. 5** Figure description (d) Question 4; (e) Question 5; (i) Question 9; (j) Question 10

Based on Figure 4(a), it was observed that 90% of the respondents agreed that they would like to use this application frequently while 10% of the respondents expressed neutral, as they found the application might be useful only in specific situations, not frequently enough to warrant strong agreement or disagreement. Regarding Figure 4(b), it was observed that 90% of the respondents disagreed that the application unnecessarily complex, while the other 10% of respondents expressed uncertainty. While for the Figure 4(c), almost 95% of respondent agreed that the application was easy to use due to user-friendly navigation and intuitive user interface, but the only 5% of the respondent state that neutral for the ease to use this application.

Regarding functionality analysis based on Figure 4(d), approximately 30% of respondents agreed that they would need the support of a technical person to be able to use this application. This is due to the application might offer advanced features that require specialized knowledge to use effectively. While for the 55% of respondents stated that disagreed due to user-friendly features and responsive design. The only 15% of the respondents expressed uncertainty. Furthermore, almost all of the respondents agreed that the various functions in this application were well integrated based on Figure 5(e). This is due to consistent user interface and smooth navigation that exist in this application.

Regarding functionality analysis based on Figure 4(f), approximately 85% of the respondents expressed disagreed to the application that have too much inconsistency and the only 15% of respondents expressed neutral due to this application have a clear documentation and user guide. Based on Figure 4(g), almost all the respondents agreed that they can imagine that most people would learn to use this application very quickly due to the simple and attractive UI interface design. Moreover, the Figure 4(h) shows that approximately 85% of the respondents disagreed that the application was very cumbersome to use and the remaining 15% of the respondents voted neutral for this situation. Moving on to the next analysis figure which is Figure 4(i), most of them (85%) was felt very confident using the application and the remaining 15% of the respondent's expressed uncertainty. This may due to the factor which is some users might prefer different types of applications or interfaces, impacting their confidence in using this particular application. For the last analysis figure which is Figure 5(j), most of them stated agreed which they needed to learn a lot of things before I could get going with this application. This reason was due to users gain a more profound and complete grasp of concepts, leading to better retention and application of knowledge throughout learning and playing at the same time.

For the last two questions which are User Acceptance Testing for Run for Health Application that shown in the Appendix E, most of them agreed that they will use this application frequently for the purpose of learning and playing (95%). They also thought the application was easy to use due to the simple and interactive UI interface design (85%).

Overall, the application could be used as a teaching aid for students in Year 1 to Year 6, which is aged between 7 to 12 years old studying nutrition in their science subject. It allows students to strengthen their understanding of nutrition interactively, compared to traditional learning methods. Additionally, the application supports research on child nutrition and its impact on health and development.

## 5. Conclusion

Based on the analysis of the testing phase results, it has been determined that the “Run for Health” mobile learning application is suitable for the target users to learn about nutrition knowledge. The project's three objectives were successfully achieved. Firstly, design an interactive “Run for Health” mobile learning application using game-based approach. Secondly, the mobile learning application was developed using Android technology and the Unity game engine. Lastly, functional and user acceptance testing were conducted following the completion of the development phase. The project adhered to the Multimedia Mobile Content Development (MMCD) methodology, ensuring timely completion. The advantages and limitations of the “Run for Health” mobile learning application are summarized in Table 12.

In terms of future work, it is recommended be challenging to delve deeply into complex nutritional concepts, leading to a more superficial understanding. Therefore, it can embed nutritional lessons within the game's story, making learning a natural part of the gameplay. For example, characters could face challenges that require understanding nutrition to solve, such as planning balanced meals for in-game characters. Furthermore, the application should incorporate a language selection menu in the settings, allowing players to choose and switch their preferred language such as Malay and English at any time. This ensures that the contents of all modules are easy for users to understand.

Finally, the application can be the design of game mechanics that inherently require the understanding and application of educational content in order to progress. For example, players might need to balance the in-game character's diet by collecting the designated foods correctly to gain energy for completing levels or solving puzzles that require nutritional knowledge. This can increase the effectiveness of the learning experience, avoiding focus more on gameplay goals rather than absorbing the educational contents.

**Table 12** *Advantages and limitations of Run for Health mobile learning application*

Advantages	Limitations
<ul style="list-style-type: none"> <li>Run For Health has shown positive results in learning outcomes, helping 7 to 12 children simultaneously acquire, play, consolidate, and revise nutritional knowledge from various categories.</li> <li>Run for Health's user interface and graphical assets are highly appreciated by its target users due to their enjoyment of the colorful interface.</li> <li>The proposed application is fully functional, with accurate display of texts, buttons, graphics, and background music, and the ability to adjust the volume of background music.</li> <li>Run for Health's 2D platformer game module is accessible and easy for children to understand, featuring simple mechanics like running, jumping, and interacting with objects. It reinforces nutritional knowledge and provides entertainment value.</li> <li>Run for Health mobile learning application serves as a home-based revision tool for children to learn, revise, or consolidate nutritional knowledge within its learning module.</li> </ul>	<ul style="list-style-type: none"> <li>Due to the constraints of the game format, it can be challenging to delve deeply into complex nutritional concepts, leading to a more superficial understanding</li> <li>The learning module does not provide completed multiple languages in learning materials and voice-over</li> <li>Players might focus more on gameplay goals rather than absorbing the educational content, reducing the effectiveness of the learning experience</li> </ul>

## Acknowledgement

The authors would like to thank the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia for its support.

## 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:** Er Jia Wei, Che Samihah Binti Che Dalim; **data collection:** Er Jia Wei; **analysis and interpretation of results:** Er Jia Wei; **draft manuscript preparation:** Er Jia Wei, Che Samihah Binti Che Dalim. All authors reviewed the results and approved the final version of the manuscript.

An author name can appear multiple times, and each author name must appear at least once. For single authors, use the following wording:

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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**Appendix A:****Table 13** *Transcripts of the user analysis*

Jia Wei: Good morning to Cikgu Suhaidah, let me introduce myself first, I'm Er Jia Wei and I'm a UTHM degree student who currently working on my final year project. In this project, I need to develop a mobile learning application for Nutrition with gamification approach. Before we start the interview, can Cikgu Suhaidah introduce yourself first?

Cikgu Suhaidah: Good morning, I'm Cikgu Siti Suhaidah bt Mohd Jalil and I'm a Science teacher from SK Pintas Raya. I had taught Science subject for about 20 years already.

Jia Wei: Thank you for Cikgu Suhaidah's introduction. For my first question, what is your opinion about the design of the application and what the application should look like?

Cikgu Suhaidah: In my opinion, I think that the application should be colourful because children like colourful things. However, the interface of the application should not be too complicated because children might get confused by the interface.

Jia Wei: Alright. Besides, are there any issues that need to be considered from the aspect of feature and navigations of this learning mobile application?

Cikgu Suhaidah: It is important to make the application easy for children to use it. Therefore, I suggest you to provide more buttons in the application so they can use the application easily. The buttons should also be designed using icons to help children easily understand how they work.

Jia Wei: Thank you for the suggestion. For my fourth question, what kind of issues should be paid attention to when developing the learning module of the application?

Cikgu Suhaidah: I suggest you to use simple words and pictures. This can make them feel more comfortable during the learning process. The game you choose should also be simple, with interactive animation, so that the children are attracted to learning and playing.

Jia Wei: Thank you for the suggestion. For the last question, do Cikgu Suhaidah have any suggestion regarding of the overall content of this learning mobile application? How should the content look like?

Cikgu Suhaidah: For the syllabus that you include in the learning module, I suggest that you refer to the Science subject textbook for year 4 students. In this way, you can easily create learning content that is suitable for 7 to 12 years old.

Jia Wei: That's all from me. Thank you so much for your valuable suggestions to improve my application.

Cikgu Suhaidah: Welcome.

## Appendix B:

Figure 6 and Figure 7 present the hierarchical task analysis and content structure mentioned in Section 3.2.

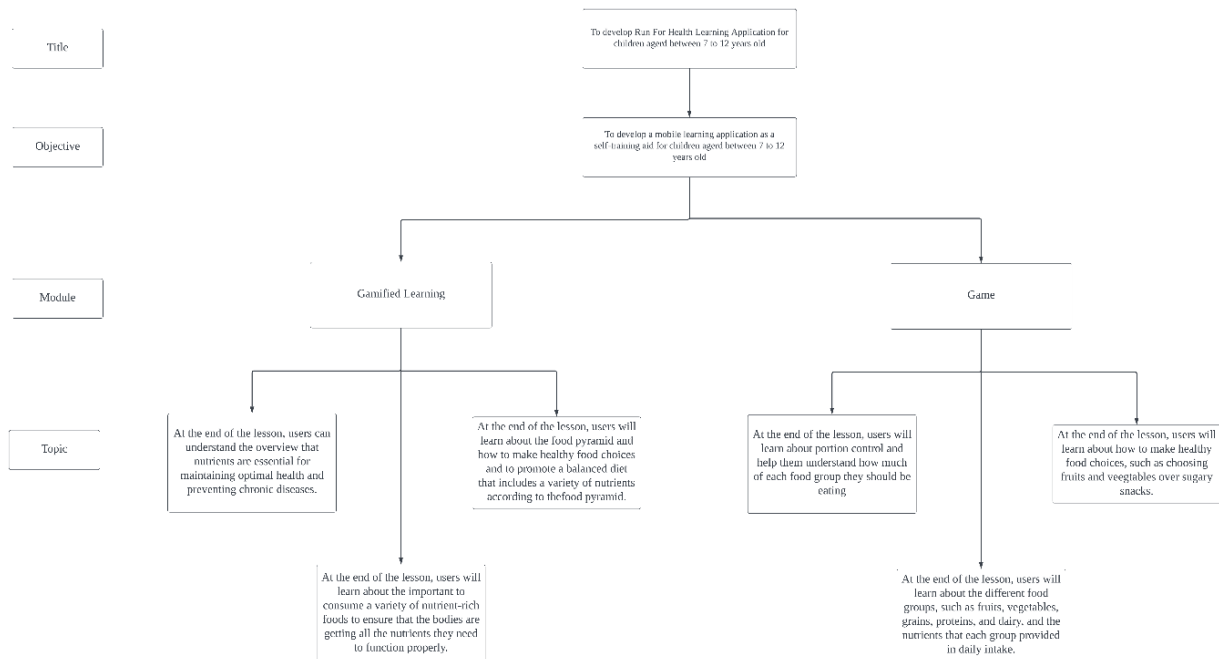


Fig. 6 Content Structure

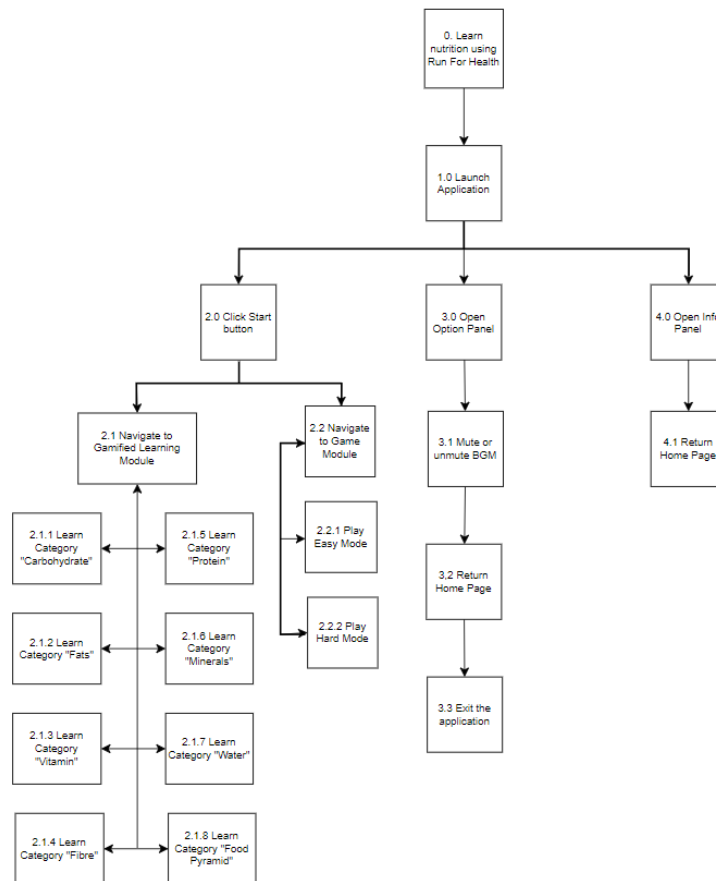
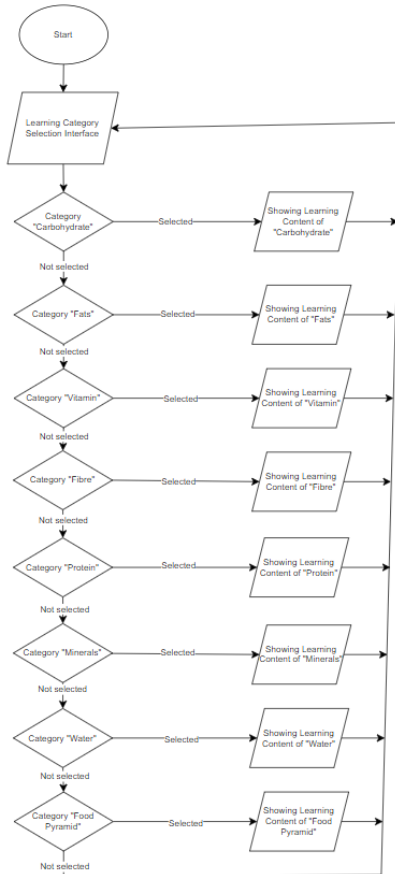


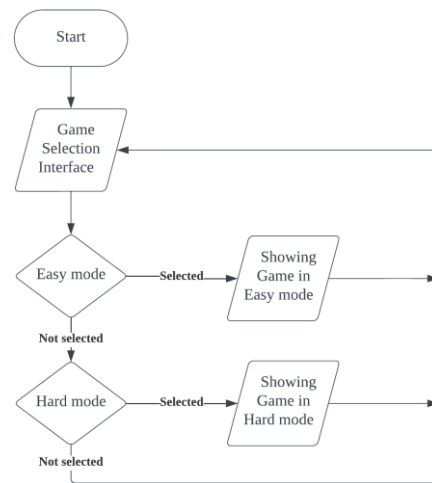
Fig. 7 Hierarchical Task Analysis

**Appendix C:**

Figure 8 and Figure 9 present the breakdown of the flowcharts mentioned in Section 3.2.



**Fig. 8** Flowchart of learning module



**Fig. 9** Flowchart of game module

**Appendix D:**

Table 14 presents the interface design of Run for Health mentioned in Section 3.4.

**Table 14** Interface design




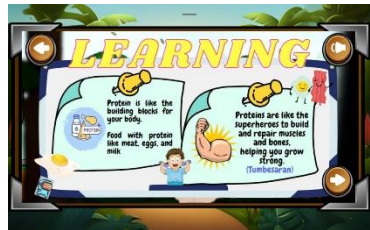













Module	Interface	Module	Interface
Main Menu		Carbohydrate Learning Interface	
Setting Interface		Protein Learning Interface	

Table 14 Interface design (cont.)

Module	Interface	Module	Interface
Info Interface		Fats Learning Interface	
Module Selection Interface		Vitamin Learning Interface	
Gamified Learning Module		Minerals Learning Interface	
Food Pyramid Interface		Fiber Learning Interface	
Food Pyramid Video Interface		Water Learning Interface	
Reward Interface		Game Module	
Game - Easy Mode		Game - Hard Mode	

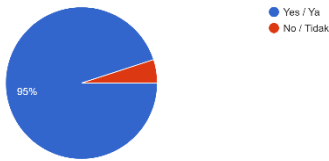
**Table 14** Interface design (cont.)

Module	Interface	Module	Interface
Winner Interface			

**Appendix E:**

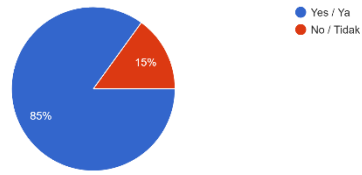
Figure 10 presents the User Acceptance Testing for Run for Health Application mentioned in Section 4.

1. I think that I would like to use this application frequently. / I think I want to use this application often.  
20 則回應



**(k)**

2. I thought the application was easy to use. / I think the application is easy to use.  
20 則回應



**(l)**

**Fig. 10** Figure description (k) Question 1; (l) Question 2