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Mobile game model for monitoring Malaysian food calories intake using image recognition

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ABSTRACT

Two important problems related to food consumption were reported in Malaysia: Malaysia was the sixth rank in Asia for the highest adult obesity rate; and the United Nation reported that Malaysian consumed an average of 2,910 calories per day. An imbalanced diet and high intake of calorie-dense food problems that need attention to reduce obesity. These problems affect national economies by lowering productivity, increasing disability, raising health care expenses, and shortening life spans. Although, there are food calorie tracking applications available, however, existing apps are less engaging and to recognize Malaysian food due to its not versatile databases. This can be solved using game technologies. Hence, this study will propose mobile game model as a solution to the underlying problems. There are 4 phases in the method: expert validation, initial model, expert verification, and final model. The proposed parameters were validated by dietitians, and nutritionists. The model was verified by game experts. A low fidelity prototype was developed based on the proposed model to assist the expert verification process. The model was finalized based on the expert's feedback. The proposed game model resolves the limited recognition of Malaysian food and monitoring the food calories intake in an engaging way.

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1. INTRODUCTION

Obesity has emerged as one of the leading worldwide concerns due to its increased clinical impact on nations [1]. According to the 2020 study, 54.2% of Malaysia's adult population is overweight or obese, up 4% points from the National Health and Morbidity survey results in 2019 [2]. With more than half of the population being overweight or obese, Malaysia is dubbed "Asia's fattest country" in an article from the star [3]. An imbalance between the amount of food taken and the amount of energy used by people results in obesity [4]. People with weight difficulties are more likely to neglect their calorie intake and regular exercise [5]. Datuk Seri Dr. S. Subramaniam, the previous Malaysian Health Minister, claimed in 2013 that Malaysians aged 18 and older had 500 to 700 additional calories daily. According to a United Nations study cited in the New Straits Times (2018), Malaysians consume an average of 2,910 calories each day [6]. This is more than the Ministry of Health Malaysia recommends for the typical sedentary man and woman, who consume 2,000 and 1,500 calories respectively [7].

The daily food calorie intake needs to be monitored to lose weight healthily and to maintain a healthy lifestyle [8]. Healthy lifestyle choices can significantly lengthen life and lower the risk of disease [9].

Most current known obesity approaches need the patient to record daily meals. However, most patients need help estimating and measuring their calorie intake due to self-denial problems, lack of nutritional information, time consumption, and usually overlooked manual techniques to record the info [10].

Food tracking apps for smartphones have grown in popularity recently. The increased demand for mobile apps that allowed users to easily log or monitor their daily food intake was influenced by society's increased awareness of the benefits of eating healthy food [11]. However, these app has two limitations: less engagement and limited Malaysian food database.

Food tracking apps are uninteresting, which results in inadequate monitoring logs and gradually saps users' drive to keep track of their food intake. Game technologies are a well-known strategy used to boost engagement and motivation [12]. A preliminary study on food image recognition apps was conducted to determine the compatibility of the existing apps and games in monitoring Malaysian food calories. The preliminary study was carried out on two food calorie tracker apps: BiteSnap and Loseit!, and two food calorie games: calorie quiz and just the facts. We discovered that, for both food calorie tracker apps, the motivation level to record the food intake decreases over weeks or days due to the inability to recognize Malaysian food correctly. These two games do not have an image recognition feature, and most of the questions are not from Malaysian food databases, making it difficult for users to report their food intake. Therefore, in this study, a mobile game model is proposed, which was developed based on serious game framework, validated by food calorie experts and game experts, for monitoring Malaysian food calories using image recognition to cater the gap. Four research questions were constructed to assist the study: i) research question 1 (RQ1): what are the appropriate parameters for monitoring Malaysian food calorie?; ii) research question 2 (RQ2): what are the components of the mobile game model for monitoring Malaysian food calories using image recognition?; iii) research question 3 (RQ3): how to propose a mobile game model for monitoring verify Malaysian food calories using image recognition; and iv) research question 4 (RQ4): how to verify the proposed mobile game model?.

This paper is organized as follows: section 2 is a literature review. Section 3 describes the methodology and method. In section 4, results and findings were discussed. Finally, section 5 conclude the main finding in this paper.

2. LITERATURE REVIEW

This section discusses four main topics that have been reviewed. The topics are serious game framework, mobile image classification by TensorFlow, game mechanics, and parameters for monitoring Malaysian food calories. Each topic discusses the findings from each review and its implication to the study.

2.1. Serious game framework

Even though games are well-known amusement, some game genres were designed for serious purposes and are referred to as serious games [13]. Nowadays, serious games are an effective medium in various industries, including education and health, because they help with training and learning by engrossing players and influencing their ideas and behaviors in a real-world setting [14]. The design-play-experience (DPE) framework presents a technique for design analysis, a design discussion approach, and a process for creating a serious learning game [15]. Figure 1 illustrates the expanded DPE framework with five subcomponents for serious game design.

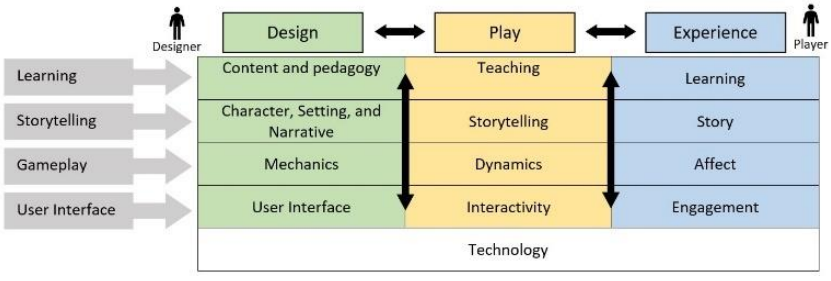

Figure 1. The expanded DPE framework [15]

In the learning layer, the designer develops the content and pedagogy that teaches the player and results in player learning. In the storytelling layer, there are two aspects of game storytelling: the designer's perspective and the player's perspective [16]. Every game has a player's story, which at least indicates how

the player handled the gameplay challenge. The gameplay layer defines what the player does in the game, the choices a player can make, and the results of those decisions [17]. The user experience layer explains the game user interface, which includes the user's interaction. The last layer is the technology layer, on which every layer is based. The game's design may only be developed based on the technology demanded. Layers make it simple to modify existing layers and add new ones. Therefore, the expanded DPE framework was adapted for proposing the mobile game model for this study.

2.2. Image recognition using TensorFlow

Image recognition is a method that employs computers to process, analyze, and interpret an image to recognize the subject [18]. An open-source machine learning system known as TensorFlow operates on a large scale and across a variety of areas [19]. TensorFlow offers two methods for mobile image recognition application programming interface (API): image classification and object detection. Image classification is a method of labeling and categorizing the whole object in a single image or defined as classifying images into a specified group [20]. In contrast, object detection is a method of identifying, locating, and detecting many objects within an image. Figure 2 shows an example of image classification and object detection.

In this study, the image classification method is used instead of the object detection method since this study aims to recognize the food image as one whole meal instead of each food item in the image. The primary purpose of image classification is to classify images into the appropriate groupings [21]. According to TensorFlow, there are three main steps in TensorFlow image classification for mobile development, as illustrated in Figure 3. An image classification model is fed photos and their corresponding labels during training. Each label designates a unique category or class that the model will come to identify. An image classification model may learn to predict whether fresh photos belong to any classes it has been trained in given enough training data (typically hundreds or thousands of images per label), and this prediction process is called inference.

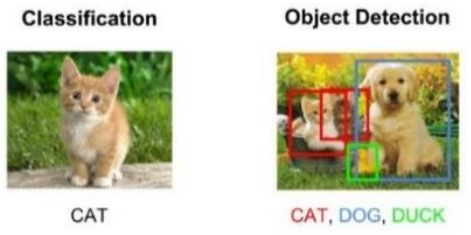

Figure 2. Image classification and object detection

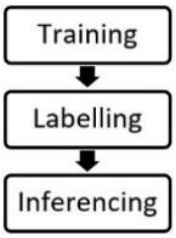

Figure 3. Steps of TensorFlow image classification

TensorFlow image classification API were used to conduct image classification tests with flowers [20], wildlife animals [22], airplanes and birds, horses, dogs, cats, and humans [23], and common garbage [24]. The test accuracies for the investigations ranged from 87.2% to 99%, which is almost accurate. Therefore, this study chose TensorFlow's image classification as an image recognition tool.

2.3. Game mechanics

Game mechanics are crucial in determining how quickly things happen and creating a sense of player engagement. An appropriate set of game mechanics pique players' interest and motivate them to invest time and effort [25]. In proposing the mobile game model, four specifics game mechanics; levels, boss battle, goal selection, and reward are reviewed.

Levels are one of the most crucial game content components in a wide variety of video games as they stand in for the virtual environment where most player interaction takes place [26]. Level refers to the variation in difficulty that indicates the user's growth status or status of progress [27]. The levels would act to track development and gradually increase the difficulty. Boss battles are special characters that are more difficult and complex to defeat than regular enemies, and their presence is indicated by a specific encounter that is strategically placed at various points throughout the game [28]. Boss fights can occur in various genres and are frequently challenging, distinct events that are different from what the player encounters throughout the game [26].

According to goal-selection theory, people might be motivated to attain objectives that range in difficulty or appropriateness for the content [29]. Goal selection should be used with incentive-oriented rewards to engage and encourage players [30]. Goal selection should be used with incentive-oriented rewards to engage and encourage players [31]. The summary results of the existing game mechanics study are shown in Table 1. All the experimental studies found positive effects of implementing the game mechanics

understudies and highlighted that there are precautions of not implementing the game mechanics properly, which is partial evidence in [22] where obscure and unclear goals resulted in lower student performance.

Table 1. Summary of the existing game mechanics in previous studies

Ref.	Game mechanics				Results
	Levels	Boss	Goal	Reward	
[22]	/	/	/	x	Unclear goal-low performance
[29]	/	x	/	/	Increase motivation, passive player
[30]	/	/	/	/	Not applicable
[31]	/	/	/	/	Not applicable
[32]	/	/	/	/	Not applicable
[33]	x	x	/	/	Not applicable
[34]	/	x	/	/	Increase motivation, passive player

The review of the serious game mechanics from journal papers had no or little clue to contribute to determining the appropriateness of the game mechanics for the study. Therefore, the researcher added a review of existing serious game mechanics for games available in the apps store, popular paid games that received a rating of 4.5 and above from thousands of paid game players. Table 2 compares game mechanics implemented by popular paid game apps in the United States (US) apps store. The researcher decided to use US apps store statistics because the total ratings by users in Malaysia apps store are few, making it difficult for the researcher to justify determining the appropriate game mechanics for the study. Findings from the table show most of the high-rated games implement levels, goal selection, and rewards.

Table 2. Game mechanics in high-rated popular serious games

Game	Total download	Rating	Level	Boss	Goal	Reward
Sudoku	978,061	4.7/5	/	x	/	/
Scrabble go–new word game	134,848	4.5/5	/	x	/	/
Peak–brain training	123,946	4.7/5	/	x	/	/
Dancing line	89,720	4.6/5	/	x	/	/
Operate now: hospital	85,668	4.5/5	x	x	/	/
Zombies, run!	17,047	4.8/5	/	/	/	/
X2 block–merge puzzle 2,048	5,161	4.8/5	/	x	/	/

2.4. Parameters for monitoring Malaysian food calories

This sub-section presents the parameters for monitoring Malaysian food calories for the study. There are two essentials' parameters considered based on the literature review conducted. The parameters are calorie intake equation, and Malaysian food calorie database.

2.4.1. Calorie intake equation

An individual needs to know how many calories are needed per day to monitor the daily food calorie intake. This is to make sure that the individual consumes a meal within the calorie limit or depending on the individual intention in monitoring weight. The researcher determined that the Harris-Benedict equation is appropriate for this research based on the suitability of the targeted sampling. This equation is used to calculate an individual's basal metabolic rate, which Harris and Benedict initially published in 1,919. This equations are used clinically to determine energy intake and formulate dietary intake for weight loss [35].

2.4.2. Malaysian food calorie database

In monitoring food calories, food calories sources are crucial to know how many calories of each food taken. As this research focuses on Malaysian food, the food database will be specifically on calorie of Malaysian food. The population in Malaysia is built of different races, Malay, Chinese, and Indian. This multi-racial became a distinctive and varied cuisine of Malaysia, known as "Asia's greatest cuisines meet and mingle" [36]. Considering Malaysia's multi-racial and varied meals, two publications by the Malaysia Ministry of Health are referred to as the Malaysian food database. The two publications are *Panduan Penyajian Hidangan Sihat Semasa Mesyuarat* and *Panduan Nilai Kalori 200 Jenis Makanan*. This finding is used to formulate the game model for monitoring users' calorie intake based on the Malaysian food database.

3. METHOD

The earlier phase of this paper focus on a literature review of four main elements; serious game framework, image recognition by TensorFlow, game mechanics, and parameters for monitoring Malaysian

food calories. The findings of the literature review have been explained in the previous section. The instruments involved in this paper are expert validation of the proposed parameters and expert verification of the proposed mobile game model. The following describes the four phases in the method for this study:

– Phase 1: conduct expert validation on the proposed parameters

During this phase, an expert validation involving a clinical dietitian and a nutritionist was conducted to validate the proposed parameters for monitoring Malaysian food calories. The proposed parameters consist of calorie intake equations and reliable sources for creating the Malaysian food calorie database.

– Phase 2: create the initial proposed mobile game model

In phase 2, the initial mobile game model was constructed based on a thorough literature review on related topics and the results of the expert validation.

– Phase 3: conduct expert verification for the proposed model

In this phase, a low-fidelity prototype was developed based on the initial game model to assist experts in verifying the proposed mobile game model. The user interface design of the low-fidelity prototype was included in the expert verification form. Three experts were involved in the proposed model verification. They were experts in mixed reality, game design, and software development.

– Phase 4: finalize the proposed mobile game model

In the final phase, all results from the expert verification session were analyzed and considered in improving the final version of the proposed game model and its high-fidelity prototype. Figure 4 shows the high-fidelity designs based on the proposed model. Figure 4(a) shows the goal screen, Figure 4(b) shows the level screen, Figure 4(c) shows the image classification screen, Figure 4(d) shows the boss battle screen, and Figure 4(e) shows the reward screen.

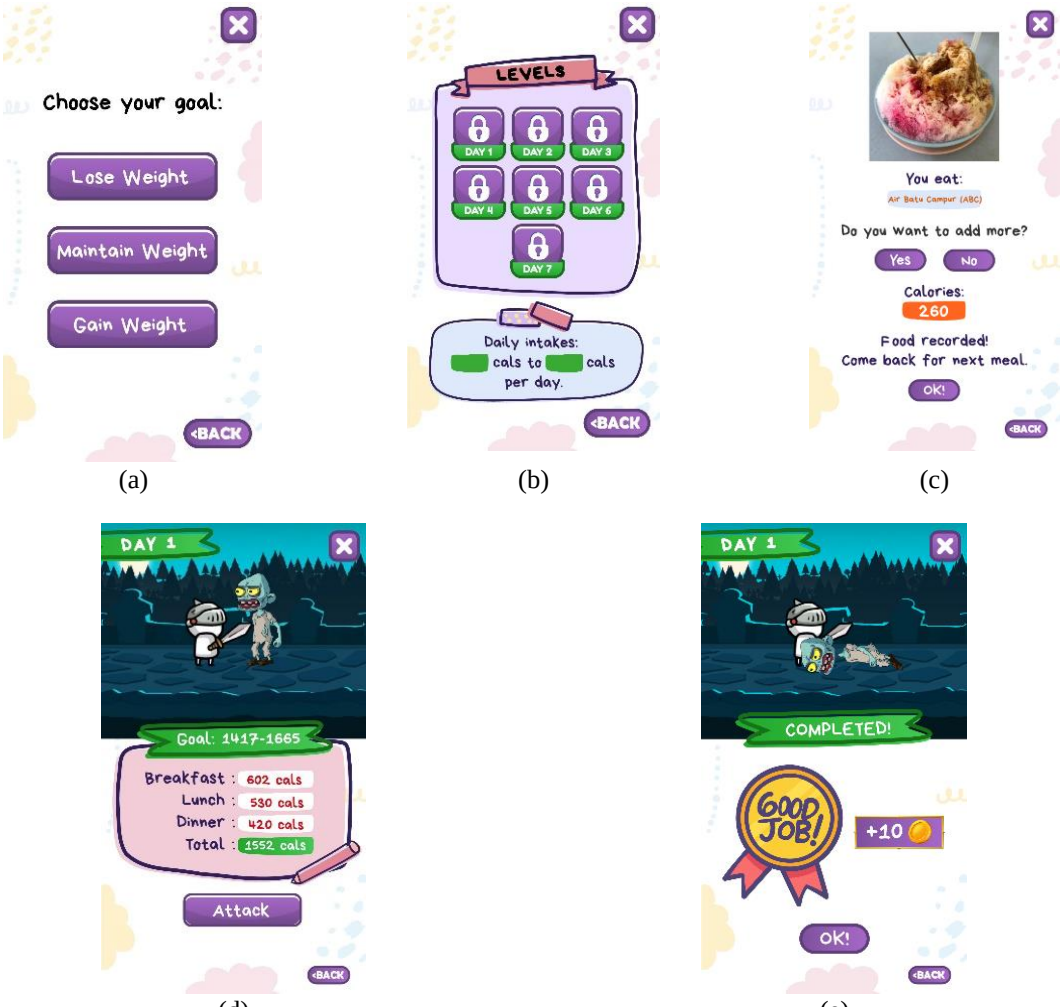

Figure 4. High-fidelity design screen for (a) the goal screen, (b) the level screen, (c) the image classification screen, (d) the boss battle screen and (d) the reward screen

4. RESULTS AND DISCUSSION

This section presents the results and analysis of the study based on the set research questions. There are four research questions discussed in this section: RQ1, RQ2, RQ3, and RQ4. The results and analysis for each research question are presented and discussed accordingly.

4.1. RQ1: what are the appropriate parameters for monitoring Malaysian food calories?

To answer this research question, a literature review was conducted to identify the appropriate calorie intake equation for this study, and to identify the appropriate sources of Malaysian food calorie database. The proposed parameters consist of calorie intake equations and reliable sources for the creation of Malaysian food calorie database is presented in Table 3. An expert validation was conducted to validate the proposed parameters, and the feedback are also shown in Table 4. Expert 1 agreed with all the proposed parameters and suggested adding one more source which is Malaysian food composition database. Expert 2 agreed with the proposed calorie intake equation and recommended a second source for Malaysian food composition database. However, expert 2 disagreed with the first source of Malaysian food calorie database because it was outdated.

Table 3. Proposed parameters and experts' feedback

Component	Expert 1	Expert 2	Summary feedback
Calorie intake equation: Harris-Bendict equation	/	/	
Source for Malaysian food calories database: *Panduan Penyajian Hidangan Sihat Semasa Mesyuarat*	/	X	This source is outdated add Malaysian food composition database
Source for Malaysian food calories database: *Panduan Nilai Kalori 200 Jenis Makanan*	/	/	

Table 4. Description of the proposed mobile game model

Layer	Component	Explanation
Image recognition for Malaysian food	Image classification	This component provides image classification of the trained image model that is implemented in the prototype to recognize food photos through a mobile phone camera.
	Malaysian food calorie database	Based on the Ministry of Health Malaysia publications on Malaysian food calories, a database consisting of Malaysian food calorie information is mapped to the trained food image model.
game mechanics	goal selections	The player is given three options for goal selections; lose weight, maintain weight, and gain weight. Players can choose their own goal. To assist players in determining their suitable goals, players need to fill in their details (age, gender, weight, and height). Based on the details, the player will be provided with a body mass index (BMI) and the weight status. The daily calorie intake will be provided depending on the selected goals.
	Levels	The game has endless levels which represent the player's daily journey. Players must complete the first level to unlock the next level. Players can unlock each level by completing the daily challenge which consumes a certain number of calories per day depending on the goal selected earlier.
	Boss battle	Each game level contains a boss battle. Players can only defeat the boss if they complete the daily challenge.
	Reward	A game text for example saying 'good job' is recommended to represent a reward of praise.

4.2. RQ2: what are the components of the mobile game model for monitoring Malaysian food calories using image recognition?

To answer this research question, a thorough literature review was conducted on the three main topics related to this study. The three topics are i) serious game framework, ii) image recognition by TensorFlow, and iii) game mechanics. The findings of the literature review have been presented and discussed in detail in section 2 of this paper.

4.3. RQ3: how to propose a mobile game model for monitoring the Malaysian food calories using image recognition?

RQ3 was answered by using results from RQ1 and RQ2 to propose a mobile game model for monitoring the Malaysian food calories using image recognition. Findings from the literature review and expert validation on the proposed parameters were used as a guideline to construct a mobile game model for this study. Figure 5 shows the proposed mobile game model for monitoring Malaysian food calories using image recognition.

The proposed mobile game model consists of two layers: image recognition for Malaysian food, and game mechanics. The top layer, image recognition for Malaysian food consists of two components which are image classification (trained model) and Malaysian food calorie database. The bottom layer consists of four components which are goal selections, levels, boss battle and reward. Table 4 describes each component of the layers proposed in the model.

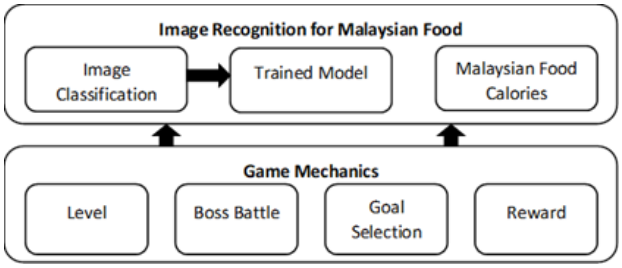

Figure 5. Proposed mobile game model

4.4. RQ4: how to verify the proposed mobile game model?

To answer RQ4, we have conducted two methods: i) verification of the proposed game model by three game experts, and ii) validation of the proposed game model by 35 participants. This sub-section presents the two main results and analysis related to the RQ4. Each result is presented and discussed accordingly.

4.4.1. Expert verification

To answer RQ4, an expert verification was conducted with three game experts in game related field. The expert verification was done by using the low fidelity prototype that was developed based on the proposed mobile game model. All the three experts agreed that the proposed mobile game model components are appropriate with a few suggestions. An analysis of the appropriateness of the proposed components for the game model was conducted based on the expert verification feedback. The trained model for image classification was increased as suggested by experts. Experts suggested to increase database for not only Malaysian food. However, this suggestion will be highlighted in future research as the paper focus is Malaysian food. The goal selection has been modified as suggested by experts to be predefined based on the initial information provided by the player. The suggestion to add more levels by weeks, adding enemies for each meal, and more bonuses if players can defeat the boss will also be highlighted in future research. In addition, one more reward was added which is points that player can redeem on a third-party app.

4.4.2. Mobile game model validation

Additionally, 35 players-18 men and 17 women-validated the proposed mobile game model. For three days, the participants log and track their food caloric intake at breakfast, lunch, and dinner using the FoodCam game. The monitoring goal for this test was for the participants to maintain their weight. Figures 6 and 7 display the total three-day goal achievement by the players as well as the test's overall food log status. The outcomes show promising results that the game can help participants keep track of their calorie intake.

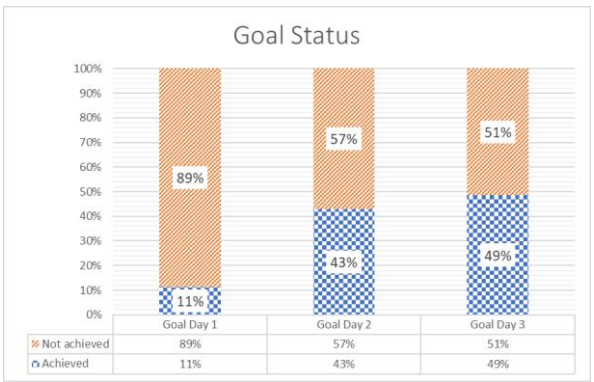

Figure 6. Three-day goal achievement

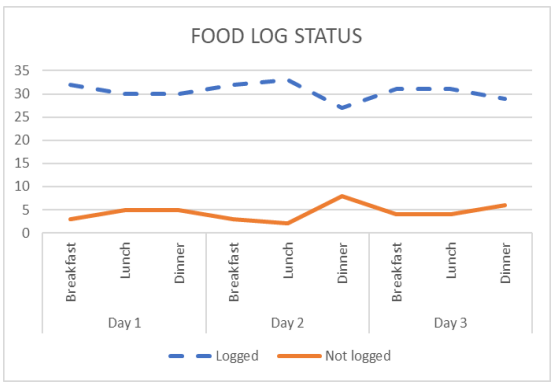

Figure 7. Three-day food log status

5. CONCLUSION

This study identified and validated the proposed parameters for monitoring Malaysian food calories using image recognition. Based on a thorough review on related serious game framework, game mechanics, image recognition methods, and having the validated parameters for monitoring Malaysian food calories, the study contributed the proposed mobile game model. The model also was then verified by game experts and the findings contributed to producing a high-fidelity prototype which was developed based on the proposed mobile game model for monitoring food calories using Malaysian food database. The game model validation by participants has shown a promising food logging effort and an increasing trend in monitoring goal achievement. Thus, the findings of the study presented the finalized mobile game model that resolves the limited recognition of Malaysian food while monitoring the food calories intake in an engaging way.

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