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Preventive Self-Care Serious Games for Diabetes: A Game Design

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Abstract. Diabetes is a significant factor that contributes to obesity. In recent years, there has been an increasing number of patients, including adults and children diagnosis of diabetes. Extensive awareness has been carried out for educating people to prevent from diagnosed with diabetes such as sharing the information through electronic media, social media, forum by medical experts, and others. However, less implementation of awareness is given through entertainment computing, such as serious games to attract people to learn in a fun way. In order to overcome the problem, a serious game to prevent diabetes through awareness was developed, namely as *Grab2BeHealthy* to educate people in choosing healthy food. The primary purpose of this study is to design the game architecture for this serious game using SGDA framework. There are a few literature studies addressed on game design framework and the implementation of a serious game in the healthcare industry, especially for awareness and diseases prevention. The game design architecture was developed using game design framework as a guideline to meet the objective of prevention. The prototype development has been tested by 50 players to proof the game design architecture.

1. Introduction

Extreme intake of calories will eventually lead to a build-up of fat in the human body, and that can lead to diseases such as diabetes. A statistics report from the *World Health Organization (WHO)* by 2016 shows that 422 million adults have diabetes. 3.7 million people dying due to the combination of diabetes and high blood glucose and 1.5 million deaths caused by diabetes [1]. Practical approaches are available to prevent type 2 diabetes and the complications of premature death from all types of diabetes. These can be including policies and practices across whole populations within specific settings (school, home, workplace) to ensure everyone become acquainted exercising regularly, eating healthily, avoiding smoking, and controlling blood pressure and lipids [2]. According to reports by the *International Diabetes Federation (IDF)* in 2017, there were over 3,492,600 cases of diabetes in Malaysia [3]. Primary prevalence of diabetes and related risk factor can classify into four categories, which are diabetes, overweight, obesity, and physical inactivity. However, we can manage to cure diabetes through monitoring (blood glucose level), proper diet (by following dietitian advice) and patients/guardians' motivation (to motivate diabetic to have the urge of managing their disease)[4]. One of the methods in preventing the diseases is giving an awareness to increase exposure or knowledge on the factor of being suffered by diabetes and how to avoid it. According to the *American Diabetes Association (ADA)*, the Standards of Medical Care in Diabetes provides the clinical practice recommendations with the components of diabetes care, treatment goals and guidelines, and tools to evaluate the quality of therapy. They have provided the standards of medical care in diabetes, including nutrition therapy, physical inactivity, smoking cessation and psychological issues [5]. Once the patient diagnoses as a diabetic's



patients, the most challenging part of the treatment plan is controlling the type of food to take and follow an advice meal plan [5]. Hence, knowledge of identifying healthy food is very important to prevent diabetes. Self-management education in controlling the people with diabetes and sharing knowledge programs is an example of appropriate awareness for people with prediabetes to receive education and support to maintain the behaviours that can prevent or delay the development of type 2 diabetes [6].

Brian Oldenburg et al. summarise the technology used recently in improving and managing diseases can consider the potential and evidence base for using contemporary technology applications and platforms within the new communications landscape to improve the prevention and management of lifestyle-related chronic diseases in the future [7]. Nowadays, serious games are widely used in healthcare industries. The implementation of serious games in increasing the awareness is proof by several examples to educate people to know the diseases such as preventing of neglected diseases [8] and empowering people with down's syndrome [9]. Development teams, including the game researcher and practitioner, play an essential role to improve technology applications to overcome public health challenges. The development of serious games can help youth learn about healthy eating and physical activity to support efforts to prevent obesity [10]. Managing diabetes prevention using serious games gives an exciting way to learn knowledge [11]. It is a tough challenge to develop the concept of self-learning applications to educate the public on preventing diseases. However, the implementation of concept can be applying through serious games due to the elements in the serious games are focusing on the learning principle embedded with entertainment elements.

This study briefly describes an overview and literature study related to the serious games design assessment framework in Section 2. In Section 3, we proposed our game design architecture for preventive self-care serious games mapping with elements in a serious game design assessment framework. The prototype development and games flow are explained in Section 4. In Section 5, we analyse the player's feedback and presented the User Acceptance Test (UAT) result and finally, in Section 6, final discussion and conclusion being address.

2. Literature Review

There are a few industries currently created a serious game for the professional purposes more than entertainment such as defence, education, scientific exploration, healthcare, management, politics and many more for learning purposes [12]. Their intended aim is focusing on understanding the knowledge of related field either as a piece of information or upskilling gap. Learning activity or pedagogy using gamification is a challenge that can improve player's understanding or practical skills while they experience it by themselves [13] and the learning approach by gamification technology adapt knowledge with fun elements to helps the learner understand the process with skills. In the twenty-first century, healthcare industries such as medical training, information sharing, and rehabilitations are applying serious games in various activity for pre-treatment, treatment, and post-treatment [14]. As indicated by Drummond, Hadchouel, and Tesniere, serious games technology in the healthcare industry is a useful tool with two main objectives, which are can motivate and educate the player [15].

There are a few serious games developed for healthcare in preventing and educating the patient. Nutrition Rush [16] is a serious game that aims to teach healthy food with nutrition. It is a preventing and awareness games created using Jump and Runs mechanics to increase player interest to play the games interactively which embedded the elements of task-based learning in the games. Another example of games application in healthcare is iLift [17] developed for nursing personnel to train them for lifting and transfer techniques to prevent lower-back injuries in healthcare. This game will not only cause the player to use correct techniques for static lifting and transferring but also revealed the necessity for future social system development, especially related to intervention acceptance using fantasy game genre and apply practice and feedback as a learning technique. A serious game for self-management healthcare designed to older adults offers the home system that implies the serious games for older adults using machine learning models for exercises recognition and remote activity supervision [18]. The goals of learning are to minimise the physical activity and offers patients to use and simulates kinesiology

exercise, answer the quizzes to improve their understanding and give feedback. This game implements intelligent tutor principles for giving feedback to the player. Its aims for preventing and self-manage the activity using exergames as a game's rules. Teaching children on eating healthy habits is a hard task for the parents. Hence, the serious games, namely as Yummy Tricks [19], is developed to educate them on this. This game genre apply to the serious game is a puzzle and apply to learn from mistakes as a principle of learning. The application tested to the three (3) children in a different stage of the game. The result shows that the proposed application was successfully engaged children on playing while learning good healthy habits. Findings of listed serious games proof that this technology can beneficially help healthy lifestyle for peoples. It can improve learner understanding and replace the conventional method of learning for prevention and awareness of diseases.

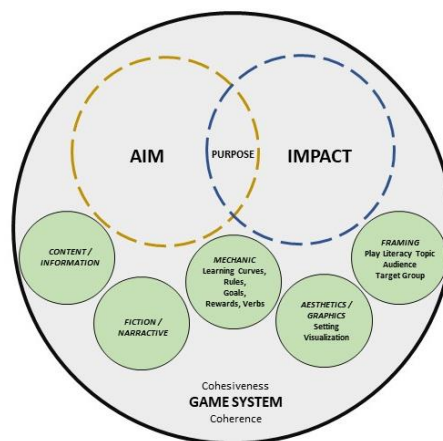


Figure 1. Serious Game Design Assessment (SGDA) Framework [22]

Generally, there are a few game design frameworks for the development serious games such as Mechanics, Dynamics & Aesthetics (MDA) framework [20], scenario-based game design framework [21], the six “I’s” of SEG design framework [22], Serious Games Design Assessment (SGDA) Framework [23] and many more.

MDA formal approach to understanding games (bridge gap between game design, game criticism, and technical game research. It consists of three (3) components which are Mechanics for game rules, Dynamics for game systems and Aesthetic for fun. The fundamental of this framework is games are like artefacts than media. Content of the games is the behaviour and streams out towards the player through emotional responses evoked by the player when they interact with the game's systems. Unfortunately, the implementation of this framework is weak when applying to the education line since there are no intelligence or coherence interaction with AI logic with the gameplay. The scenario-based game design framework is used to develop a system architecture and the associated tools for efficient scenario-based game development. It consists of three (3) parts which are conceptual level, technical level and practical level. The conceptual level in this framework explained the static game configuration and game environment. It can be comprising into four (4) subsystems: the gameplay, the learner world, the teacher world and the game management world. The technical level is a tooling system implemented in game development. The architecture of this level comprises four (4) types of tools which are location builder, object builder, role builder and scenario builder. Finally, on top of the conceptual level and technical level to develop serious games, the practical level should incorporate to support the development of complex serious games. The levels cover the topics of game structure, feedback and game representation. It is used to reduce the complexity of feedback and representation of game design. However, the framework will be more established with the evaluation of learning outcome for certain scenario-types — the six “I’s” of SEG design framework derived from developing and testing educational games. The component consists of Identity, Informed Teaching, Increase Complexity,

Interactivity, Immersion and Identity. It is based on combination from research and theory in education and psychology with instructional technology and learning science.

Finally, the fourth game design framework, Serious Games Design Assessment (SGDA) framework are designed for constructive structure to develop purposed-based games. It consists of seven (7) components which are purpose, content or information, fiction or narrative, mechanics, aesthetic or graphics, framing and game systems. Figure 1 shows the serious games assessment design framework. According to this framework, game design starts with the game purpose with the combination of aim and impact of playing the games to player. The aim should reflect directly to the purpose of playing and its topic. Next component in the framework is all the information visible to the player, facts and data offered to display or show to the player while playing the games. The third components are game mechanics where the developer must consider the learning curve of playing the games. The games method are invoked by the games agent for interacting the game world. It also uses for the establishment of the rules of operation in the games including rewarding systems, obstacle or challenge and the winning condition. The game mechanics also translate the verbs or action in-game world into the rules and algorithm. Fourth, the fiction and narrative flow are used to create a situational space and relate to the game purpose. The context of fictional includes the characters in-game space, settings, narrative story, backstories, scenario and problems. The narrative story could be a linear story, simulate, represent issues or created by the player. Fifth, the aesthetics and graphics is a basic element to introduce the game purpose and impact on the player. Usually, it is representing the audio-visual language which is the aesthetic characteristics, imagery, style preference, artistic media and computer games technique. It also conceptualized and visualize to display important elements to the player. Example of the important elements is the content through descriptive information, fiction as a game character, framing to focus the target group, game settings and game mechanics as instruction and rewarding systems. Besides the five (5) key components: purpose, content & information, mechanics, fictions & narrative and aesthetics & graphics, the framing are the important components to specify the target group of players. It is used to control the play literacy of the game purpose and the broader topic of content or information. The framing can essentially influence the gameplay experience. Finally, the coherence and cohesiveness of the game system used to show how it holistically relates to each other between the game purpose and all the components. It also worked as an integral entity to shape the gameplay experience. The massiveness of game system leads to the conflict in a gameplay.

Game design framework is essential to implement in the development of the serious games to ensure the achievable of learning objective with experiencing the game world in a fun way. Unfortunately, some of the game design frames is not suitable to implement with specific issues.

3. Game Design

The serious game architecture for prevention and self-care awareness of diabetes or known as *Grab2BeHealthy* was designed using Serious Games Design Assessment (SGDA) framework to guide on the prototype development. The development process embedded the adoption concept of software development life cycle in order to help in improving the comprehensiveness of the requirements and satisfaction of player [24]. Figure 2 shows the game design architecture for *Grab2BeHealthy*. The game design architecture of *Grab2BeHealthy* refers to the seven (7) elements in design framework, which are purpose, content & information, game mechanics, fiction & narrative, aesthetics & graphics, framing and game systems.

Figure 2 shows the game design architecture of *Grab2Behealthy* serious games with guidance from the SGDA framework. The primary purpose of the development is to give awareness on balancing diet to the player by choosing the suitable food for healthy life. The main aim or mission of this game is differentiating healthy and unhealthy food. After they complete the mission the games should help the player to choose and categorize healthy food in their daily life. The heart of the serious games is the content and information. This game offer tips on differentiating the food, healthy food, unhealthy food, timer, score and the total score to the player as a fulfilment of content and information. Next element is

a game mechanics which are roles as a mechanical part in a game. This element creates rules using algorithm to control the action in a Grab2BeHealthy such as how to avoid from unhealthy food, catching or grabbing the healthy food using basket, collecting the suitable food and moving the basket using mouse controller. It is including the operation of rewarding system while collecting the correct food, obstacle and challenge, the difficulty of each level by speed and how to calculate the score to win the games.

In order to create a narrative story and the fiction of serious games, the arrangement of character, games setting, game stories, backstories and main problem have to clearly identify. The main problem created in Grab2BeHealthy is people usually take more unhealthy food in daily life which cause obesity and diseases. Based on the problem, scenario has been identified and created, where people quickly get unhealthy food. It is to create stories where people usually experiencing the situation. Next is the aesthetic and graphics which are fundamental to introduce the game purpose and give experience to the player through visual graphics and head-up display (HUD) in games interfaces. Grab2BeHealthy starts with the image of the impact if people not choosing healthy food in life which are overweight and obesity. It also shares the tips on choosing the food before starts playing the games. Fact and information related to the healthy food also display in between each level to remind and keep the player on track of the purpose of playing the games. Music and graphics are embedding and design in a 2D to keep player exciting with the mood of challenging.

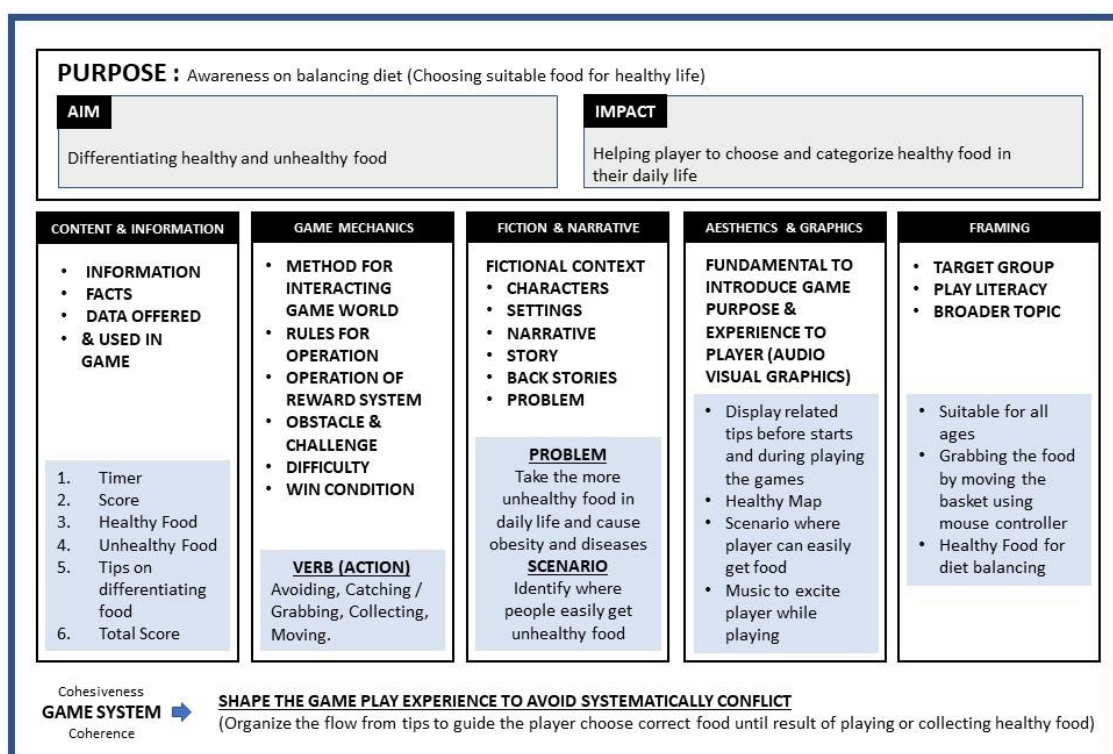


Figure 2. Grab2BeHealthy Games Design Architecture

Framing of the development is important to create the scoping area of game purpose. Grab2BeHealthy is targeted to all suitable ages. The main play literacy is grabbing or collecting the healthy food by moving the basket using mouse controller to get score within time given and the difficulty of each level. The broader topic of this games is healthy food for diet balancing. Overall cohesiveness and coherence of the game system are used to shape the gameplay experience in order to avoid conflict systematically. The cohesiveness of this games is clearly identified to organize the flow from tips to guide the player until the result of playing or collecting healthy food.

4. Prototype Development

The prototype development is based on the effect cause unbalance diet or taking more unhealthy food than healthy food. To start the games, the player must read the guideline or list of food that can choose to collect rewards score. Given guidelines are works as awareness to the player to differentiate healthy and unhealthy food. Two (2) types of information as in Figure 3 shows the guidelines and knowledge for diabetes prevention.

In the beginning, the player must choose the category then the player will see 2 pages of instruction food that they should grab and shouldn't grab. The games continue with level 1, and there is a lot of food combined with healthy and unhealthy food drop in a slow mode. The player must recall the information given on the previous page and grab healthy food. It is a compulsory requirement where the player must expose with either direct or indirect knowledge as an awareness. The mission started when the player was aiming to grab food, as shown in the instruction earlier. 5 points of marks will be adding to the score result as a reward in level 1 and minus 3 points from score result if the player grabs the unhealthy food. Games will continue to level 2, where the challenge will increase with the increase of speed in a food drop. Each collected unhealthy food will minus 4 points, and 5 points of mark will be adding as a reward if the player collects the healthy food successfully. The player will continue to level 3 with a challenging obstacle where the food drop in a fast mode.



Figure 3. Guidelines and knowledge for diabetes prevention.



Figure 4. Example of the game environment (scenario) in *Grab2BeHealthy*

The penalty of 5 points will be deducted from the current score if the player grabs the healthy food and they will get another 5 points of marks if they catch good food for health. The process of counting the marks is a mechanical process in the game engine to increase the challenge of the games. In between each level, the player must read tips as a piece of additional knowledge to them to prevent and awareness regarding diabetes. 60 seconds are given to the player to grab the food for each level. The games share feedback on reward's result and achievement after completing the games. Figure 4 shows examples of the scenario in the game environment.

5. Result

The games were tested and accepted by 50 participants with basic computer knowledge (22 Male and 28 Female) and various age range from 18 to 50 years. 68% from them are exposed to diabetes knowledge either from media, books and family history. The results show that 52% of the tester agree with this application suitable to use for awareness purposes while the other two motivation, which is 28% suitable for prevention and consultation purposes. 20% from the tester agree that this application can be used for teaching purposes.

User acceptance test result was collected and categorized into components in game design architecture. From the pie chart in Figure 5, it is apparent that 60% of player agrees with the gameplay mission while they played the games. However, another 40% disagree with the aims. Interestingly, most of the player agrees with the arrangement and design for the game engine, which contains game mechanics and challenge. Of the overall response to the questionnaire, 96% was reported to agree with rewards and penalty given to the player, and another disagrees with their own reason. The most surprising feedback is 98% of the player agree with the challenge in the games. The feedback on game engine shows in Figure 6.

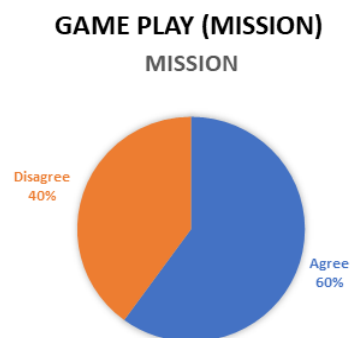


Figure 5. User Acceptance for gameplay in Mission

On average, gameplay for feedback in Fig.7 shows that only 46% of player agrees with the overall prototyped development game. However, the concept of games using game design architecture mostly satisfied based on overall feedback as they get benefit after playing the games. Table 1 shows the feedback on overall prototype development using game design architecture and agrees with the alternative platform using serious games to educate the consumer on a healthy diet for diabetics' patient.

Table 1. *Grab2BeHealthy* Games Characteristics

Feedback	Agree	Disagree
Players get the benefit after playing the games.	50	0
Alternative awareness platform to educate the consumer on a healthy diet for diabetics' patient.	50	0

GAME PLAY (FEEDBACK)
SUMMARY OF COLLECTED POINT

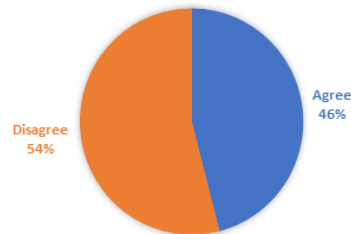


Figure 6. User Acceptance for gameplay in feedback

GAME ENGINE (GAME MECHANICS)

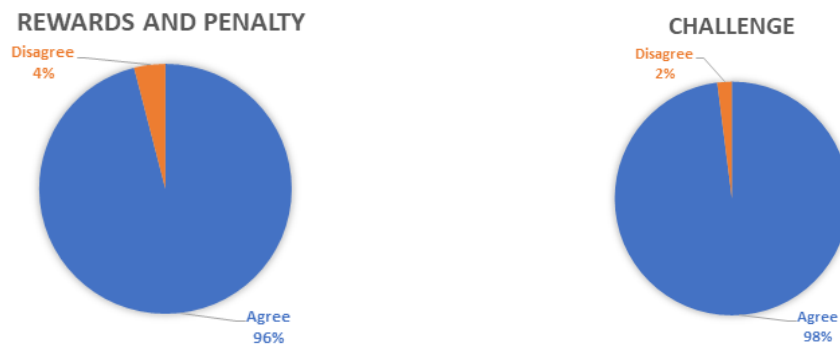


Figure 7. User Acceptance for the game engine in game mechanics

6. Conclusion

In this study, game design architecture for preventive self-care serious game for diabetes by differentiating healthy and unhealthy food was developed to utilize the compulsory elements in the framework, such as the purpose, content & information, game mechanics, fiction and narrative, aesthetics & graphics, framing and the game system. The implementation of the framework into the design helps player to increase the understanding and attract various age range to understand the facts of healthy food in a fun way. This application used to educate and give awareness to people related to diet and differentiate healthy and unhealthy food using technology tools.

The application suitable for various range of age and implement puzzle games as a game's genre that suitable to the learning technique such as memorization, feedback, practice, and others. The repetition of activity in this game can encourage the player to memories the information compared to reading. Based on the survey result, all tester agree that they get to benefit from the application after playing *Grab2BeHealthy*. There are a few reasons how people have diabetes such as lack of physical activity, smoking cessation and depression. Self-care preventive management helps to minimize the risk of getting diabetes. The application is not limited to the information learning but increasing the human activity that leads to the reducing risk of diabetes. The current implementation of awareness, such as article, video sharing, and graphics illustration is one-way information. The interactive application gives them more enjoyable and improves memorization, especially on the do and don'ts. We aim for the data monitoring enhancement of the games by embedding the physical activities to increase the understand and awareness of diabetes to the public.

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