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2D Platform-based Game of Arithmetic Game-based Learning

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Abstract. Mobile games have attracted attention among game developers and users. Throughout the years, mobile games have developed to become one of the domination of the digital world. They have evolved from just a non-coloured with few animated dots and lines to a coloured and more realistic three-dimensional gameplay. Besides, mobile games do not only act as an entertainment but also as a medium for improving mental arithmetic skill if the content is designed accordingly. However, most of mobile games nowadays have been developed for leisure purpose only. There is less game on IQ test and education while more on skills and action alternatively. Hence, arithmetic game-based learning application is developed as an alternative to be included in the variety of gameplay or content of the game. The game created based on platform genre with endless running style. Arithmetic questions are provided in the gameplay as one of the obstacles to both provide challenges and IQ test for the players. This game is implemented in mobile platform. Technology Acceptance Model (TAM) is adopted to measure the game quality based on the evaluation of user acceptance level towards the gameplay, functionality and playability, and overall performance of the game. Overall, 50% of respondents agreed that the gameplay is satisfying. In addition, 40% of respondents strongly agreed that the functionality and playability of the game is stable and the overall performance of the game functions perfectly.

1. Introduction

A mobile game is a game which characterized as game played in handheld devices with or without network functionality [1]. Besides, it can come in preloaded and also can be downloaded by users from any available store such as App Store and Google Play or the internet. Nowadays, mobile phones specifically smartphones have a broad series of connectivity features like Bluetooth, Wi-Fi and 3G. These type of technologies allow users to even engage in wireless multiplayer games which can involve two or more players. There are several types of mobile game genres available such as adventure, arcade, platform, puzzle, strategy, shooter, role-playing, simulation, sports, survival, and hybrids [2]. Among them, platform-based game genre is one of the most popular game genre in market place. This game genre involves the movement of the character through a series of platforms to avoid obstacles while collecting items if there is any available. Traditionally, platform-based games are side-on 2-dimensional (2D) in perspective and very popular on earlier gaming platforms. Playing digital
games has become a popular pastime amongst children. On average, children aged 8–18 spend 50 min per day playing digital games [3]. Playing digital games also reported as the second most common activity after finishing schoolwork [4].

However, mobile games have indirectly become an issue as the games developed are more violent-based [5]. Some of the games in store have also caused feelings of aggression and violence to exist within an individual. The simulated violence of certain genre of games may affect a player's thoughts, feelings and physical arousal. Hence, this in turn develops a short term and probably a long term effect on a single person's judgment of an aggressive act [6]. Not only that, there are people who get addicted to the games too easily once played repetitively. In addition, other games were mainly developed simply for leisure purpose with no values added. Therefore, a 2D platform-based mobile game-based learning application, called Defeatobot is developed as an alternative to be included in the variety of gameplay or content of the game. In addition, the gameplay of Defeatobot is a simple one-button game in which players have to drive a character to pass the obstacles. The game contains arithmetic questions as one of the obstacles in which player has to answer in a fast and precise way. Thus, the gameplay is hoped to enhance students' arithmetic skills.

The rest of the paper is presented as follows: related work discusses about mobile games as learning strategy in arithmetic. Next, the methodology describes the mobile development process, followed by the section that discusses the results. Finally, the concluding remarks are presented.

2. Related Works

Mobile games have played a crucial part in human life since the existence of it. However, mobile games did not obtain wide recognition even though they have existed for a long time until the appearance of new colour handsets with better usability, sound and Java technology. Not only that, mobile games have received a lot of attention due to the popularity of smart devices since the improvement in the design and features of the current games. Mobile games have been widely applied as an alternative approach in learning strategy. Shin et al. [7] investigate the effect of game technology on elementary students learning mathematics. In this study, students who played technology-based arithmetic games outperformed students who played paper-based arithmetic games. Research also found that, playing games can lead to gain in accuracy and calculation speed and improvement in attitude towards mathematics in 10 to 11 years-olds [8]. Findings in [8] also confirmed by [9] where playing an educational games could help second grade pupils improve their arithmetic skills as well as can increase their accuracy compared to paper exercises or no exercise. Moreover, the mathematics games can increase mental calculation speed in a similar way as an equivalent number of paper exercises. In terms of affective outcomes, playing the game was reported to be more enjoyable than filling out the paper exercises [9].

3. Methodology

Defeatobot mobile game application is developed in Android based operating system. Game Development Life Cycle (GDLC) [10] is applied to develop the game application. There are six phases involved in the development of Defeatobot game: initiation, pre-production, production, testing, beta and release. Detail explanation of each phase will be discussed in the following topic.
3.1. Initiation phase

Initiation phase involves creating a rough concept of what kind of game that will be created. The output of initiation is the game concept and a simple game description. Table 1 shows a sample of the game plan document produced for Defeatobot game.

| Item                  | Description                                                                 |
|-----------------------|-----------------------------------------------------------------------------|
| Game Concept          | 2D side-scrolling, Platform Game, endless game style                         |
| Game Theme            | Educational Game                                                            |
| Educational Content Value | Drill and practice about arithmetic                                       |
| Character Name        | Robot                                                                       |
| Obstacles             | Mechanical gearbox, arithmetic questions (randomly generated)               |
| Other features        | Boosters and game life                                                     |
| Environment           | Famous landmarks and skyscrapers of Malaysia                                |
| Storyline             | Defeatobot is a game that requires player to navigate the Robot past the obstacles (mechanical gearbox) while answering the arithmetic questions throughout the gameplay. In the beginning, the player is given 3 lives. If the player obtained certain score, power-ups booster will come out to help player get rid of the obstacles as well as increasing the score if the player managed to answer the next arithmetic questions correctly. |

3.2. Pre-production phase

Pre-production involves game design and creating game prototype. Game design focuses on defining and preparing game genre, gameplay, mechanics, storyline, characters, challenges, fun factors, technical aspects, and game design document (GDD) or storyboard. Defeatobot game implements single playing mode that is offline playable. The setting of this game focuses on local content with the famous landmarks and skyscrapers in Malaysia, which are displayed in a more futuristic style by using a friendly robot as the main character of the game. Those landmarks are presented as game scene background. The graphics creation was completely in 2D graphics design as it is of a parallax scrolling style of gameplay. Thus, it does not require the game to be in three dimensional environment. In terms of gameplay strategy, the game structure is designed as an endless running where player has to play until it reaches zero live before they can start a new gameplay. In this game, the player must consistently control the character to fly upward. Player has to drive the character through the game by passing the obstacles while gathering as many collectibles as they can. As for the obstacles, this game uses gearbox and arithmetic questions which appear at random position to obstruct the player. The player needs to escape the arithmetic obstacles by choosing the correct answer before it reaches the character. Each question has four options of answer. Once the player chooses the correct answer, the obstacle itself will disappear and thus, the player can continue with the gameplay. Any correct answer will gain 10 marks and vice versa. The purpose of applying arithmetic obstacles is to activate player’s mental arithmetic while increasing their calculation speed. Besides having obstacles, this game also provides power-up booster to player in order to accomplish the mission. Meanwhile, there are two iterations happened in this phase: first iteration produced a form of prototype’s foundations and structure; second iteration produced a complete prototype.

3.3 Production phase

Production phase is the main activity which involves the assets creation, source codes creation, and the integration of both elements. The output of this phase is a formal and refined prototype. Production phase involves the game development starts by preparing all kinds of game assets for example, text, graphics, buttons, characters and audio. Those assets are created using specific software. The game assets are arranged according to the planning done in the storyboard. The assets such as character, props and buttons are scaled to the appropriate sizes and organized correctly in particular arrangement.
of the game application. After completing the assets creation, integration of all assets are performed to produce complete scenes as shown in Figure 1 and Figure 2.

The game consists of seven scenes such as introduction, main menu, instruction, high score, about game, credits, and gameplay. Each scene holds a certain amount of buttons and functions. For example, the main menu scene has four buttons namely play, high score, credits and about game, as shown in Figure 1. They are arranged according to the standard arrangement of game main menu. As for the gameplay scene, it has two buttons which include pause and ‘fly’ buttons as in Figure 2. They are organized at the positions where it can be visible to player. Figure 2 depicts the gameplay when player meets the arithmetic obstacle, multitasking action should be performed. The player needs to control the character by tapping the ‘fly’ button and at the same time answer the arithmetic question correctly in a shortest time. At the end of the game, a high scoreboard of the game is displayed. Only the top five player will be listed on the scoreboard.

Next, single source code for the prototype is created by using C# programming language. Figure 3 depicts the code segment which allows character to be controlled by player in the game. The character can only move to the right continuously, or fly up or fall down during the gameplay. Besides that, the background of the gameplay was integrated by using parallax scrolling of a game effect as shown in Figure 4. After completing the source code creation, the assets and scripts are integrated in Unity software to execute the application in the correct way. Unity 3D software is used as game engine that
enable user to interact in mobile platform. C# programming language is chosen to be used in Unity to implement the game application. Android Application Package (.apk) file is needed for the Android platform installation. This script linked the objects and scenes together, and allowed the player to interact with the game and navigate through the application.

3.4 Testing phase
In this phase, formal details testing (alpha testing) are performed using playtest by developer internally to assess the game functionality and playability. Game functionality testing involves game stability, integration of game assets. Any bugs, loopholes, or dead-ends during playtesting are discovered and fixed. Meanwhile, game playability testing involves testing the ease and correctness of tapping method used to control the main character and navigate through the game environment.

3.5 Beta phase
Beta phase is to conduct external tester called beta testing. Technology Acceptance Model (TAM)[11],[12] is adopted to measure user acceptance level in terms of gameplay, functionality and playability, and overall performance. The game is released to a limited number of users in online and offline form. Online beta testing was carried out by sending the .apk file to 20 target users via Google Drive. The respondents downloaded the file into their Android device and answered the questionnaire in Google form. Offline beta testing was conducted by 10 target users within the organization.

3.6 Release phase
Release phase is the time when the game build has reached final stage and ready to be released to public. However, Defeatobot game application is released internally within the organization for educational purpose.

Table 2. Technology Acceptance Model for evaluating game quality

| Construct             | Evaluation variables | Measured item                                                                 |
|-----------------------|-----------------------|-------------------------------------------------------------------------------|
| Perceived of usefulness (PU) | Gameplay (arithmetic obstacles) | PU1: I found that this game is fun and interesting to be played          |
|                       |                       | PU2: I found that this game is challenging to be played               |
|                       |                       | PU3: I found that this game is able to activate my arithmetic skill      |
| Attribute of usability (AU) | Functionality and playability | AU1: The game is stable when played in mobile device  |
|                       |                       | AU2: The control buttons work perfectly in the game                    |
|                       |                       | AU3: The integration of game assets is implemented perfectly          |
| User satisfaction (US) | Overall performance   | US1: The navigation of the game is easy to understand and control      |
|                       |                       | US2: The screen design is suitable with the theme featured in the game |
|                       |                       | US3: The words and illustrations are suitable in each screen display     |
|                       |                       | US4: The presentation of the information and instruction is clear     |
|                       |                       | US5: The aesthetic/art value in the game is good                      |
|                       |                       | US6: The icon buttons are compatible with their respective function    |
|                       |                       | US7: The overall game application functions perfectly                |
4. Results and Discussion

The game application was successfully built with the size of 1280 x 800 pixels resolution and less than 40MB memory size. User testing was carried out to evaluate three variables based on TAM: users’ acceptance level towards the gameplay approach (arithmetic obstacles), functionality and overall performance. 30 respondents of the age of 16-34 were involved in the testing. Table 2 shows the construct and measured items adopted from TAM to evaluate the game quality.

Figure 5 shows that 57% respondents agreed while 33% strongly agreed that the arithmetic obstacles are interesting. Furthermore, 60% respondents agreed and strongly agreed the game is challenging and activate mental arithmetic skill, respectively. Conversely, only 3% respondents disagreed that the game was challenging. In terms of game functionality and playability as in Figure 6, more than 40% respondents strongly agreed that the game is stable. Interestingly, more than 50% respondents strongly agreed that the game has good button control and integration of game assets. Conversely, 3% respondents disagreed that the game has good button control. This is due to unfamiliar game control using respective control button. Meanwhile, Figure 7 shows that more than 40% respondents strongly agreed that overall game performance criteria worked well and have been achieved the game objectives.
5. Conclusion and Future Works

Overall, it can be concluded that the implementation of arithmetic obstacles as the gameplay in Defeatobot mobile game application has potential to be used as an alternative way of learning approach. Compare to other casual mobile game, Defeatobot is able to stimulate user to think and having fun while playing the game. Future enhancement is needed to improve user acceptance criteria in terms of its gameplay criteria as well as increasing performance level criteria for more convenient and user friendly mobile game application.

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