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Discover Mathematics on Mobile Devices using Gaming Approach

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Abstract

Mobile device has become a common gadget among the society. The once known only for the wealthy, the device allows people to communicate, work and play. Playing mobile games in mobile devices has become a trend as it can be played anywhere, anytime. Mobile device has properties like portability, connectivity and social interactivity that make it a preferred platform for learning. Hence, the usage of mobile devices can be expanded to mobile learning, where the learning environment is not restricted in classroom only. Computer games can also be highly effective in increasing children's learning and enjoyments of mathematics. By combining the fun factor of mobile games, the flexibility of mobile learning and the benefits of games, mobile educational games was developed. This paper discusses the model for the development of a mobile educational game for primary one mathematics education. The model describes the components that are required for the development of a mobile learning. The components for the model are the learning theories, learning approach, gaming approach, and the delivery medium. The prototype development process combines the instructional systems design and the game development approach. The developed prototype has been successfully tested using the functionality test which tested the govern on stability, correctness of game mechanics and integrity of game assets.. The result showed that learning Mathematics on the mobile devices through gaming approach is possible and can become a promising alternative learning approach.

***Keywords*:** Children; Educational game; Mathematic; Mobile learning

1. Introduction

With the rapid growth of the mobile devices such as mobile phones, PDA and portable game devices, the demand for better and useful applications of mobile device has increase. The advances of wireless technology create a new learning model that is the mobile learning. Mobile learning has been proven effective as an educational application in recent empirical studies (1). The term mobile learning suggests a kind of learning supported or enhanced by telecommunication device or electronic mobile device (2). Compared to traditional desktop learning, mobile learning focuses on the mobility of the learning practice and promotes the interaction between the learner and learning content. However, mobile learning is not intended to replace the classroom learning but as an enhancement or an augmentation to the value of mobile devices and telecommunication network (3). Mobile learning also enables the delivery of learning content through mobile devices. In order to achieve this, the learning content needs to be developed specifically for mobile devices capability. It needs to be in a small and compact form so it can be delivered using wireless network. Hence, mobile learning is not about converting all desktop based learning content into a mobile learning, but it's about how mobile devices can be used to enhance overall learning strategy (3).

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Mobile phones are becoming a part of daily culture for almost all young generation. However, only few mobile applications are for learning purposes (4). Young generation normally used mobile devices as a platform for playing games (5). Research conducted by (6) reported that about 6 million people downloaded games to their mobile devices each month. Researches done by (7) illustrated that integrate learning with entertainment, called as 'edutainment'. In their project named as MobiGP (Mobile Games for Programming Learners), one of the objective is to develop a mobile game for student to improve their programming knowledge. The significant of the project is learning and having fun at the same time can make the students learn faster and more efficient. The use of handheld devices has made the application easy to access anytime and anywhere. The attractive features are also important to attract game players to play the games. The project showed that students are able to gain knowledge and skill while playing games, and this present opportunity to expand the study towards broader audience, especially school children and teenagers.

The linkage between goals 'winning the game' and 'learning the material' and also the implementation of intrinsic motivation which will raise the efficiency of learning is important for games to be an effective educational tool (8). Refer a study by (9), there are seven key factors for creating an intrinsically motivating instructional environment. The seven factors are: challenge, curiosity, control, fantasy, cooperation, competition and recognition. All these key factors must be adopted when developing an educational game.

The growth of mobile devices and the potential of the electronic games have led to the ideation of designing a mathematical educational game for children, the MathRush. MathRush was designed within the portability and flexibility of mobile devices.

2. Designing the MathRush, Discover Mathematics on Mobile Devices

Designing for the MathRush involves designing the framework, mobile interface and the technical strategy for the game. The design is translated into a storyboard for easy development. The framework for MathRush was designed based on the game model called JELAJAH (10).The framework for MathRush consists of four main segments that are (i)Learning Theories, (ii)Mobile Learning Approach, (iii) Games Development Approach and (iv) Learning and Education Medium.

Constructivism has been chosen as the learning theory. Constructivism learning theory is to develop self directed learners who are able to access a wide range of cognitive structures, and transfer the learning to other contexts that they have not encountered yet (11). According to (12), constructivism requires learners to construct their own understanding by trying to practice what they have learnt and the real world application. A study by (13) has also applied the constructivism approach in their educational game to teach business. The game level design and mechanics for this game is developed based on this constructivism theory.

For the mobile learning approach, the game uses activity based themes for informal and lifelong learning (14). This approach is to support learning outside dedicated learning environment and make it suitable for the application which is to complement formal learning environment. Research done by (15) agreed that theories of learning in mobile environment must highly take the consideration of learning outside of the classroom and moved from situated learning to mobile learning which allows learning to take place at learner's usual and preferred place. In the Game Development Approach, games' criteria are used to determine how to develop the prototype application using the learning modules that have been determined. The game criteria include goals, rules, competition, challenge, fantasy and entertainment. The criteria guide the development of a game to make it interesting and applicable to any situation. MathRush has adopted all the criteria in order to develop a real game-play experience for the audience. Table 1 below describe the games criteria and explain how they are adopted in the application:

Table 1. Adapting the games criteria in MathRush

Games Criteria	Description of function
Goals	The player is informed of the goals of the game. They know what they are required to do in order to complete the game level. The instructions are explicitly given in the game menu. In each level, the player will be challenged with different random equations, and the player needs to find a box which contains the correct answer as fast as possible.
Rules	The rule is implemented in the game as it governs the organization structure of the game. It is the rules of the game-play. The rule such as time limit or meeting specific demand to advance to the next stage will be implemented.
Competition	User will compete against time limit as they try to solve to equation as fast as possible.
Challenge	To add excitement to the user, the platform layout has been designed to challenge player agility to pass through obstacle.
Fantasy	The game world will base on fantasy environment such as dungeon exploration and jungle exploration. MathRush brings the player to fantasize of being in the maze in search of the correct answer.
Entertainment	The application will provide fun learning experience towards the user with the attractive music and graphics.

In order to effectively deliver the learning material in the application, the appropriate delivery medium is required, not only it will enhance the presentation but also to instigate interest among the student. The learning and education material is delivered through interactive multimedia components. Below are the multimedia components and its function for the application:

Table 2: Descriptions of multimedia elements in the application.

Multimedia Components	Function
Graphics	Graphics is important to represent the look and feel of the application. Due to the limitation of graphic capability of mobile devices, the graphics for this application is scaled to meet the limitation. Simple graphic sprite is used in the game level. The character uses the low resolution sprite to save memory space
Animation	Animation is used to deliver the movement expression in the game. For this game, the only moving object is the character, where several animation including, walking, running and jumping need to be rendered. However, due to limitation of mobile devices, the character animation is designed with minimum amount of animation to the movement of the character.

Text	Text is used to deliver the textual data for user to read and understand the application. The text is also used to display the equation and time in the game level.

Figure 1 below illustrates the framework for the mobile educational game that has been discussed earlier.

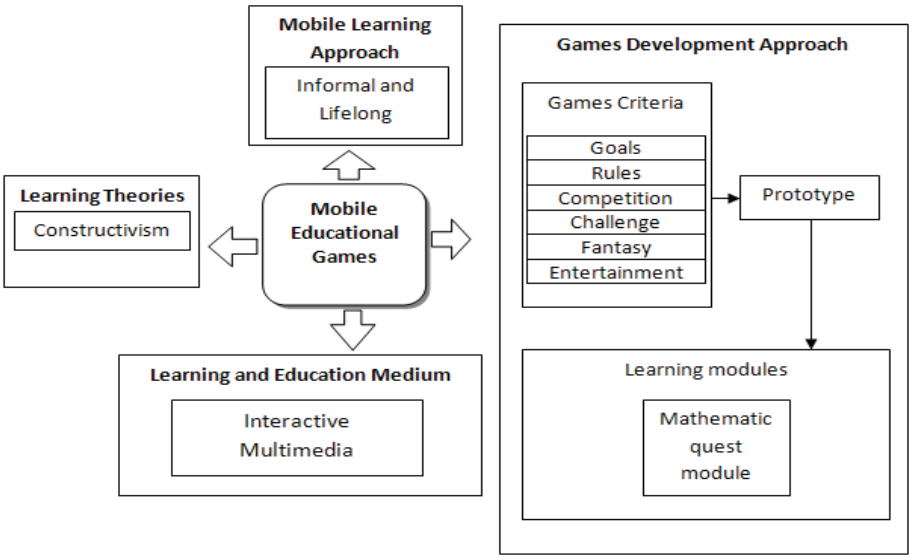

Figure 1: Mobile Educational Games Framework

The learning modules in the MathRush game is structured for easy and user friendly interaction. Once launched, the player will be greeted with the main menu screen. The main menu contains the selection of menu elements for the player to choose which are the, “Start Game”, “High Scores”, “Instructions” and “Exit”. Start Game selection will start the game for the player. The High Scores selection will display the score board that have been stored by the game. The Instructions selection will display the game instruction for the new player. It also explains in brief the game goal and how player can achieve it.

3. Game Structure

The game starts with a randomly generated equation based on standard mathematical operation. The random number generated for the equation is limited to basic mathematical operation such as addition, subtraction, division and multiplication. The answer for this random equation will be hidden in the box scattered in the game world. The placement of the answer is randomized, where the correct answer is not at the same box each time the level begins.

With most of the mobile phone or device come with the directional keypad, player can control the avatar or character using it. However, the game also provides alternate key input through the numerical keypad on mobile phone. However, this game does not support mobile phones that are using touch screen as the main method of input. Players are required to control and navigate the character in the game world to find the box containing the answer for the equation.

When the player found the box containing the correct answer for the equation given, the clock will stop and a notification to notify that the player has found the correct answer will be displayed. Player is now required to register their name to be displayed on the score sheet. The player whom are able to find the answer in the fastest time will get a highest score in the score sheet. The game structure is as shown in Figure 2.

Figure 2: Game structure design layout

The MathRush game is a 2D scrolling platform genre. 2D platform games are easy to play and playable with the limited capability of the mobile phones or devices. It also requires less computing power than 3D game genre.

4. Game Development

Game development includes development of the graphics, game level and animation. All are designed and assembled together. The prototype was developed using Java 2 Micro Edition (J2ME) with Netbeans 6.1/6.5 as the authoring tools. The development focused on the creation of game level and also random equation generators that is needed for the application. The prototype specification that has been developed is as follows (table 3):

Table 3: MathRush! Prototype Specifications

Prototype Name	MathRush
Version	0.0.10
Platform Type	CLDC/MIDP
Emulator Platform	Java(TM) Wireless Toolkit 2.5.2 for CLDC
Device Configuration	CLDC-1.1
Device Profile	MIDP-2.0
Screen Size	320 x 240
Included Abilities	JSR 226 SVG

The prototype also implemented new JSR 226 (8) SVG API to allow Scalable Vector Graphics animation been implemented as part of the application. The JSR 226 defines an API for rendering 2D graphics as what has been defined by World Wide Web Consortium (W3C) Scalable Vector Graphics (SVG) Tiny format. With this API, it is now possible for developers to create interactive graphical content. As comparison with traditional raster graphics, SVG is much more scalable as it allows zooming and resizing of the image without loss of quality. SVG also enable text search within a graphic, allowing developers to create interactive user interfaces.

The SVG codes were written in XML which is a new feature of Java ME. SVG allows the prototype to have a nice set of splash screen and menu graphics. SVG promises to be much lighter and efficient if compared to the traditional graphics format currently used for Java ME applications such as PNG or JPG (8).
The game starts with the player character starting on top right of the maze. Random equation is positioned on the top right corner of the screen, while the timer on the top left corner of the screen. The box containing the answer of the equation is positioned in the level with one of the box containing the correct answer. The goal is to find the box with the correct answer in the fastest time possible.The screenshot of the prototype running in emulator environment are as follows:

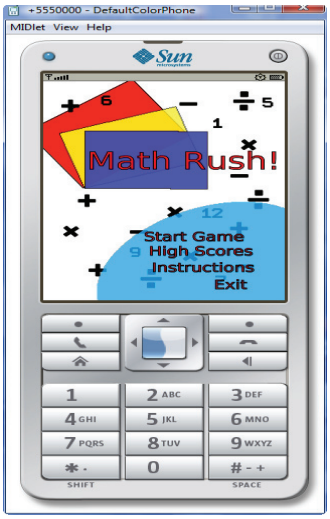

Figure 3: MathRush! - Main Menu

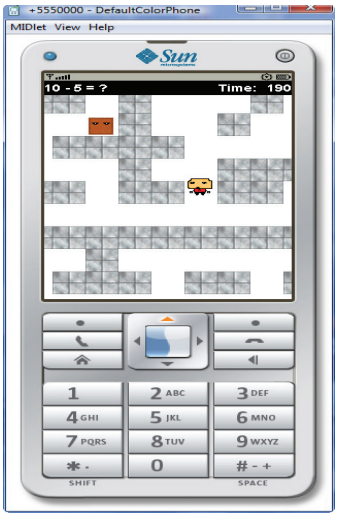

Figure 4: MathRush! – Sample of Game Level

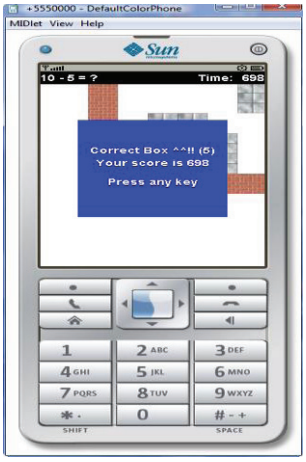

Figure 5: MathRush! - Game Over

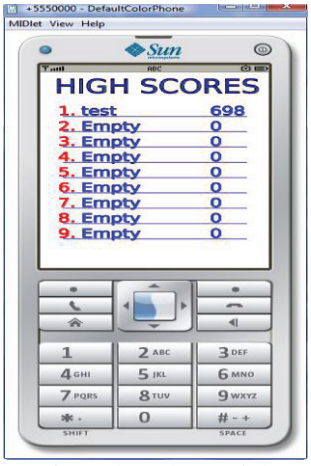

Figure 6: MathRush! - High Score

Figure 3 showed the main menu. It has a simple interaction menu to let the player interact with the game functions. It was developed using SVG. Through the menu, player can choose to start game, view instructions, view the high score or exit the game. Figure 4 showed a sample of the game level. The player is required to walk along the maze in order to reach to the correct answer. There are two main challenges in the game that are to find a correct answer which is in the box and to move along the maze against the time limit. A good game should include challenge as one of the game features as challenge is said to motivate players to continue playing and eventually will learn the subject matter unnoticed (16). Figure 5 showed the 'Game Over' screen which is shown once the correct answer is found, the victory screen will be displayed to indicate that the game is over. Figure 6 showed the 'High Score' stored for

the game. The player is required to key in their name to register it into the high scores table. Once the player registered their name, the high scores table will be displayed.

5. Testing

The prototype of the game is tested to ensure that the prototype is developed according to the specifications from the earlier design phase. A functionality test has been conducted for that purpose. Functional testing will verify the functions available in the prototype. It will test whether the prototype works and functions as stated in specification document. The functional areas of the game that are tested are stability, correctness of the game mechanics and integrity of the game assets.

5.1 Stability

The game was first tested on the Java Wireless Toolkit Emulator platform. The prototype did not show any stability problem running on the emulator environment. The stability of the prototype has also been tested on several other mobile phone devices. The first mobile phone it was tested was Motorola W510. According to the Motorola website, W510 fully support CLDC 1.1 and MIDP 2.0 applications. However, the game crashes, as soon as the tester tries to launch the game.

The second mobile phone used for testing is Sony Ericsson K750i. According to Sony Ericsson website, K750i fully support MIDP 2.0 applications. However, same as the W510, the game crashes as soon as the tester tries to launch the game. With the stability issue on standard MIDP 2.0 mobile phones, testers moved for smart phones, running on Windows Mobile. The smart phones was HTC P3600i running Windows Mobile 6.0 Professional and equipped with powerful Samsung 500Mhz processor. According to HTC website, the phone is fully capable for running MIDP 2.0 applications. However, the expectation is fall short as the result of the test is the same as previous test, the game crashes right after launch.

With the stability has been an issue on several mobile devices, efforts were taken to fix the stability problem. The result of the investigations for the cause of the crash was the new implementation of JSR226 which is not fully supported by those mobile devices.

With the help of Java ME community, the recommended mobile devices for running applications with JSR226 application is mobile phone from Nokia, running S40 as main operating system. Tester found the suitable Nokia phone, Nokia 6500 Slide. Nokia website stated that 6500 slide fully support MIDP 2.0 applications. Tester found out that the prototype running on the phone, however with the slight slower performance with the prototype part where SVG animations are implemented. This concludes that further research is required to enhance on the stability of the application on multiple mobile devices.

5.2 Correctness of the Game Mechanics

This test is to identify any errors in the game mechanics. The game mechanics that are put to test is the random number generation, equation generator and the movement of the character. The random equation generator component which is the crucial part of game mechanics has been tweaked to avoid it from giving illegal arguments or equations. The prevention measure has been put to prevent the generator from generating division by zero equation, negative numbers and extreme high number for equations.

The answer for the equations is randomly distributed among 5 boxes in the game level. However, the answer is not visible on the box. The player needs to guess the box to find the correct answer. The random distribution works correctly, and the character movement is smooth. Overall, the tester satisfied with the correctness of game mechanics.

5.3 Integrity of the Game Assets

Game assets are the texture interface, character and answer boxes appearance. This test looks for any error in the game assets integration. Each texture that been applied in the game is examined to ensure the texture are correct and function as planned. The prototype uses very few textures, to cope with the mobile device limitation and to increase performance. The testers did not observe any texture corruption and instability. The testers were satisfied with the game assets integration.

6. Conclusion

With the advancement of mobile phone technology, the increasing processing power and memory space are open for any developer to develop application for mobile phones. By combining both mobile learning and mobile games, it will provide user with a new experience like no other. The game has been developed to harness the potential of mobile education application.

The game has been infused with the educational material, with the mathematic as its main theme. While the game may look simple, the game provides challenge for the user or student who just started to learn the basic principle of mathematics and having fun at the same time. The game is also mobile and can be played anywhere.

As for the technical side of the application, Java ME and Netbeans 6.1/6.5 is the most suitable for the beginners to start developing mobile applications, however the knowledge about object oriented language is necessary. The new JSR226 SVG API has a lot of potential for more advance implementation in mobile application.

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