The Sixth International Conference on e-Learning (eLearning-2015), 24-25 September 2015, Belgrade, Serbia

GAME BASED MOBILE LEARNING – APPLICATION DEVELOPMENT AND EVALUATION

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Abstract: *Game based mobile learning is becoming increasingly popular in the world of rapid scientific and technological changes where mobile devices provide support for multimedia content, location awareness, augmented reality and connectivity. However, just having technical features does not make a game either engaging or pedagogical. The challenge for designers of games for mobile learning is to provide both effective gaming experiences and learning outcomes into the same application. This paper presents an approach for developing a mobile game-based learning application named "Geostep". The application is an interactive mobile learning framework designed for both formal and informal educational scenarios. The concept of development and playing of mobile educational games has been tested and evaluated in different groups of students and teachers at University "Mediterranean", Montenegro.*

Keywords: *Game based mobile learning, Evaluation of mobile educational games, Geostep*

1. INTRODUCTION

Mobile devices and their applications provide significant advantages to users in terms of portability, location awareness, and accessibility. Improvements of the hardware and software capabilities of smartphones and advanced broadband, multimedia and mobile telecommunications services has led to huge numbers of mobile applications being developed over the past few years. Rapid technology development has significantly influenced all aspects of human life including education.

Modern students have grown up using Internet and mobile devices. They are mostly information-literate people, which always, participate in standard communication channels such as social web communities SMS, e-mail, chat rooms, etc. Using technology represents a way of life of modern students, rather than separate activities, which can be used for work and learning [1-3]. But already in the early stages of life it is hard to motivate students to stick with the learning process: on the other hand, students enjoy playing games.

Reasons for this can be found in the goals that games include, e.g. beating the game and fellow players, collecting points and rewards, and the fact that playing games itself is engaging.

Two approaches have been used interchangeably to transform educational situations to game-like experiences: gamification and game-based learning (GBL). While gamification turns the world into a playable and meaningful game in order to achieve specific objectives, GBL applies concepts to interpret the meaning of existing game worlds or reframes the game worlds as "playground" for experimentation and analysis of concepts [4]. The research on GBL increases dramatically worldwide [5] and this is due to the fact that the growing usage and popularity of exploiting game to support learning [6].

Mobile game for learning or mobile educational game (Game Based Mobile Learning - GBML) is a game specifically utilized for learning which is also played on a mobile phone, smart phone, PDA or handheld devices. Similarly to game-based learning, the main aim of GBML is to use game play to enhance motivation in order to learn, engage in knowledge acquisition, to enhance effectiveness of learning content transfer or other specific learning outcome [7].

Developing a good educational game is very important in ensuring the learner is motivated enough to keep playing the game until the game (educational) goal has been achieved [1], [8], [9]. Mobile educational games are designed to enable learners to play games "on the go" while mobile. The impact that the use of mobile devices has on the mobility of the user is a critical factor to the success or failure of the application [10]. Small screen sizes, limited connectivity, high power consumption rates and limited input modalities are just some of the issues that arise when designing for small, portable devices. In addition, the development of mobile educational games is complicated from both the technical and conceptual standpoint. Most of design methodologies are guidelines

and general approach for developing mobile game and not GBML.

This paper describes a concept, technological overview and methodology for usability evaluation of a platform named GEOSTEP [11], developed at Faculty of Information Technology, University "Mediterranean".

GEOSTEP platform supports the game-based mobile learning concept, and enables an advanced type of education. The paper is structured as follows. Section 2 presents some of generic premises of mobile usability, followed by description of the methodology for evaluation of MGBL. Section 3 includes GEOSTEP platform functional description, game-play procedure and short technical description. Section 4 presents platform evaluation and results.

2. METHODOLOGY FOR USABILITY EVALUATION OF GBML

Mobile usability

The usability evaluation is conducted to users in order to find out how the users easily and efficiently can reach the application objectives. The usability of mobile devices and their applications differs from other software systems, because their characteristics are different. The advent of mobile devices has presented new usability challenges that are difficult to model using traditional models of usability. Zhang and Adipat [12] highlighted a number of challenges that have been introduced by the rapid deployment of mobile devices, such as: Mobile Context, Connectivity, Small Screen Size, Different Display Resolutions, Limited Processing Capability and Power, and Data Entry Methods. Also, software embedded in the phones during manufacturing or installed by customers from various mobile software distribution platforms, such as Apple's App Store and Google's Android Market affects development and usability of mobile

applications. At the same time, mobile device manufacturers provide guidelines and recommendation for development of mobile applications considering their own usability constraints. For example, the Apple iOS Human Interface Guidelines [13] states the iOS platform characteristics that should be considered during the application development process, and Google Android user interface guidelines [14] explains characteristics that should be considered during the development and testing of Android applications.

A number of additional studies have focused on the usability of mobile devices [15, 16], and currently the list of usability heuristics is described in [17]. Some modifications and additions have also been made to the evaluation which also considered being useful [18]. These studies are more focused on the general applications not specific to game. Specific to games for learning, Malone has developed the first heuristics for evaluating educational games [19] based on three categories: challenge, fantasy, and curiosity. The main purpose of the heuristics is to serve as a checklist for designing enjoyable user interfaces. A set of heuristics have been proposed by Korhonen and Koivisto [18], that can be used for evaluating any mobile game which consists of three modules: Game Usability, Mobility, and Gameplay.

Heuristics described in [17], [18], [19] should be considered for GBML evaluations, but they were not described specific to GBML Therefore, in this study we have used methodology for usability evaluation of GBML adopted from Zaibon and Shiratuddin [20] which adds a new component Learning Content to overcome the limitations of previously mentioned heuristics.

Components of evaluation strategy

The adopted heuristics evaluation strategy which consists of four components: Game Usability (GU), Mobility (MO), Game Play (GP), and Learning Content (LC) can be implemented for usability evaluation of any GBML.

Table 1 describes the interface and game controls with which the player interacts with the game. In general, good interface of game and usability ensure that the player have interest to play the game until the end.

Table 1: Game usability components

No.	Game Usability Components
GU1	Audio-visual representation supports the game
GU2	Screen layout is efficient and visually pleasing
GU3	Device UI and game UI are used for their own purposes
GU4	Navigation is consistent, logical, and minimalist
GU5	Control keys are consistent and follow standard conventions
GU6	Game controls are convenient and flexible and game was adapted to my screen size
GU7	The game gives feedback on the player's actions
GU8	The game contains useful help

Next, in Table 2, the Mobility consists of three components which concern about the issues that affect mobility of the game. Mobility can be defined as the easiness of a player to enter to the game world and the accessibility of the game anywhere and anytime.

Table 2: Mobility components

No.	Mobility Components
MO1	The game and play sessions can be started quickly
MO2	The game accommodates with the surroundings
MO3	Interruptions are handled reasonably

The eight Gameplay Components (Table 3) specifically describe how the game is playable, runs smoothly and consistently, is meaningful, and not boring to player. The GP is important because it is dynamic and occurs when

the player interacts with the game mechanics and rules.

Table 3: Game Play Components

No.	Game Play Components
GP1	The game provides clear goals
GP2	The player sees the progress in the game and can compare with other players
GP3	The players are rewarded and rewards are meaningful
GP4	The player is in control
GP5	Challenge, strategy, and pace are in balance
GP6	Game strategy (out of classroom) is adequate for learning activities
GP7	The first-time experience is encouraging
GP8	There are no repetitive or boring tasks

Lastly, the Learning Content Components, as listed in Table 4, are specifically concentrated on the learning content. The LC components should provide informative, useful, and understandable content to the users when playing the GBML.

Table 4: Learning Content Components

No.	Learning Content Components
LC1	The game provides learning content
LC2	The content can be learned easily
LC3	The learning objective from the game is achieved
LC4	The content is understandable

3. GEOSTEP PLATFORM

Functional description

GEOSTEP [11] is a platform for creating and playing interactive geolocation games, based on treasure hunt game rules. It consists of a web application, where anyone can create a game for free, and a mobile application that is used for downloading and playing games.

Game master (creator of the game) defines data like game name, short game description, number of clues in the game, game type and privacy, time frame in which a game will be active, estimated path length in kilometers and estimated duration in minutes. For each clue, game master creates a riddle, chooses exact location on the map where the clues will be hidden and sets the diameter of the clue circle that users can see on the map. This circle defines the area where the clue is hidden and users need to find it by using game instructions. When the creation of the game is finished, a PDF file that contains clues in the form of QR codes is generated. The game master receives the unique game code that can be subsequently used to access the game using smartphones.

There are three game types: regular, time attack and educational game. In regular game the winner is the first user who has found all clues. In time attack game the winner is the user who has found all the clues in the shortest time. In educational games users are ranked according to the points they receive for correct answers.

Games can be public or private. If the game is marked as public, players will be able to find it through the "Public games" menu item that shows all games in the vicinity. Also, players can apply filters and choose any other location on the map to find available games. If the game is private, players need to know unique game code in order to start a game.

Gameplay procedure

Gameplay procedure is held through mobile application. Player needs to choose, download and install the game to start the "treasure hunt". On the map, players will be able to see the location of the circle area in which the first clue is hidden as well as their own location. In order to successfully find a clue, a player needs to resolve the given riddle. Finding the clue is facilitated by the fact that the clue circle area changes color depending on the proximity of the clue (hot-cold game principles). After finding the clue, the player scans a QR code. Scanning the correct code will give the location of the next clue as well as a new riddle to solve. The same procedure should be repeated for all clues in the game. After scanning the last clue, the player can send results to server and compare with other players on the ranking list.

Game creation and play procedures for educational games are different in the fact that every answer is scored. During educational game creation game master specifies the maximum number of points. Those points are equally distributed to each question (clue). Each question is connected to one location where multiple QR codes with corresponding answers are hidden, only one answer i.e. QR code being correct. In Geostep mobile application player sees question and circle which defines an area where the answers are hidden. They should find the place where QR codes are hidden, but also choose correct code to scan in order to proceed to the next question. They attempt to answer the question until they reach the correct answer. In accordance with the number of attempts player receives points for that question. If answered correctly in the first try, the player receives 100% of the points for that question; second try would give them 50%, the third 25% and the fourth and the following 0.

After answering all the questions (finding all the clues), player has to check in the result. Result takes into account the points won as well as the time in which the game was completed. If the player finishes the game within estimated time specified by game master, the points from all the answered questions are summed together and they represent the final score. If player exceeds that time, negative points are given for each second of delay and the final score is calculated by the equation (1):

$$FS = PW - (TD * MP / (ET * 2)) \quad (1)$$

The abbreviations having the following meanings: FS – final score
PW – points won by answering questions
TD – time difference in seconds between achieved time and estimated game time
MP – maximal number of points in the game

ET – estimated game time in seconds

At the end players will be presented the ranking list, which contains position, username, number of points won, number of negative points and the final score for each player (Figure 1, bottom right).

Figure 1: Game play process for educational game

Technical description

The architecture of the Geostep platform (Figure 2) consists of:

- database – MSSQL database located on SQL Express server,
- web application – used for game creation, and
- mobile applications – used for gameplay.

Figure 2: Geostep architecture

MSSQL database provides easy and free setup, with decent performances and allows unlocking a spatial index also for free, which was crucial for implementing some of the features Geostep platform has (i.e. Finding public games in the vicinity from the mobile application). Potential problem with choosing this technology is scalability, as it only allows limited number of connections. This limit could be exceeded if Geostep platform becomes widely used in which case purchasing a full version of SQL server would solve the issue.

Web application, besides game creation and tracking functionalities, also provides:

- Web services for communication with mobile applications. These services include receiving requests, performing CRUD operations on the database and responding on them in XML format.
- Dynamic creation of spatial queries
- Algorithms for creation of QR codes and serving them in PDF and PNG format (with requested size up to 4000x4000px)

Using ASP.NET and the features of the SQL Express database in combination with Java Script and JQuery, contributed to creation of a fluent and logical web interface. Google Maps API provided necessary functionalities for displaying and controlling maps.

The mobile application used for gameplay is currently only for Android platform. Developed in native environment, application uses SQLite database and various third party libraries in order to achieve its functionalities, such as QR code scanning, displaying animations, pie charts etc. In order to communicate with online SQL Express database, it uses web services provided by Web application.

4. GEOSTEP EVALUTION AND RESULTS

The platform was first tested and evaluated by a group of internal experts, trying to identify design flaws, bugs or any other problems that may occur during the platform usage. Some issues were identified and the platform was updated and optimized. In second step the evaluation is conducted with students in real-life scenarios in order to find how usable the application is for users.

We organized two separate events at the end of summer semester with different groups of students and asked them to perform educational game of their choosing. The technical equipment used consisted of a phone with Android OS 4.0 or newer. The educational games offered were developed by teachers who had some initial support of the platform development team. Games clues were located within city of Podgorica.

At the beginning, all game participants were given a short demonstration of the platform and some instructions. The instructions were very general and related only to the system functionality, without any instructions concerning the game scenarios.

Figure 3: Question and offered answers example

The games offered were intended to assess knowledge from two courses: Introduction to IT and Programming, at the Faculty of Information Technology. One game is created for each course. Each game contains five questions with four answers offered. Example of question is shown on figure 3.

Basic game data is the same for both games. Maximum number of points is 20, i.e. there are 4 points per question. Estimated game time is 25 minutes, and estimated path length is 1.5 kilometers.

Results

Total number of students that participated in games was 29. Introduction to IT game was played by 11 students, and Programming was played by 18. Table 5 shows some basic facts about the evaluation groups and games played.

Table 5: Overview of participants per age and gender

Age	Males	Females	Total
20	3	1	4
23	11	1	12
24	-	2	2
25	4	2	6
26	2	1	3
32	2	-	2
Total:	22	7	29

Among participant there were those who play mobile games (66%), in varying amount of time (up to 1h daily), and those who do not (34%), as presented in figure 4. the Average time spent playing mobile games was 25.2 minutes, which is 9.7% of average daily time spent using mobile phones (261 minutes). Based on this we can presume that they are experienced users and should provide relevant feedback.

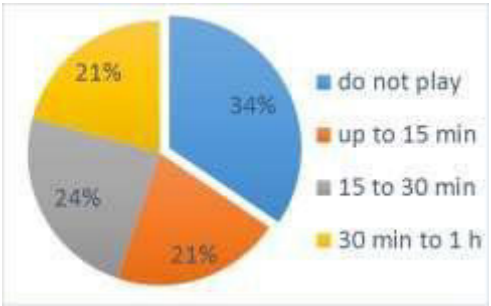

Figure 4: Average time participants spend daily on playing mobile games

Participants used their own mobile phones for testing purposes. There were both newer and older phones (up to 5 years old), all versions of Android OS from 4.1 to 5.1, screen diagonals from 4" to 5.7" and resolutions from 480x800 px to 14400x2560 px. This all contributed positively to diversity and relevancy of the users' experience and feedback.

Results that students achieved, concerning scores and achieved time, are presented in tables 6 and 7. All students achieved more than 50% of total points and only some exceeded the estimated time by no more than 5 minutes. According to those results we can conclude that the estimated time was in accordance with the difficulty of questions.

Table 6: Results by scored points

Game / Points	Max	Min	Average
Introduction to IT	20	16	18
Programming	20	10	15

Table 7: Results by achieved time

Game / Time	Longest	Shortest	Average
Introduction to IT	29	17	21
Programming	30	17	22

After finishing the game students were asked to complete survey presented in chapter 2.2. Survey results in Likert's scale, as average marks for each statement (blue bars) and overall for component (orange bars), are presented on figures 5, 6, 7 and 8.

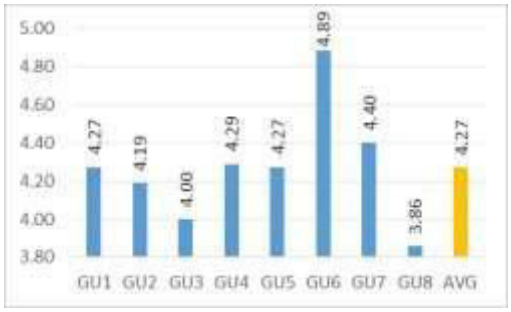

Figure 5: Average marks for Game Usability components

Of all GU statements, the worst marked was GU8 "Contains useful help" which clearly indicates that users, at least for the first time, needed better in-app guidance and explanations along the way. Overall, users were satisfied with user interface, so we can assume that no major changes are required.

Figure 6: Average marks for Mobility Component

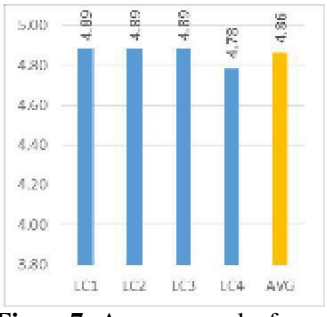

Figure7: Average marks for Learning Content component

While the users were satisfied with general responsiveness of the game (figure 6), relatively poor mark was noted for statement MO3 "Interruptions are handled reasonably", mostly referring to loss and/or inaccuracy of GPS signal. This could be solved or at least lessened by better implementation and use of GSM/UMTS triangulation algorithms in cases when GPS might fail.

The best marked statements, as well as component overall, were Learning Content (figure 7), proving that the

integration of LC and mobile games in this case produced the desired effect.

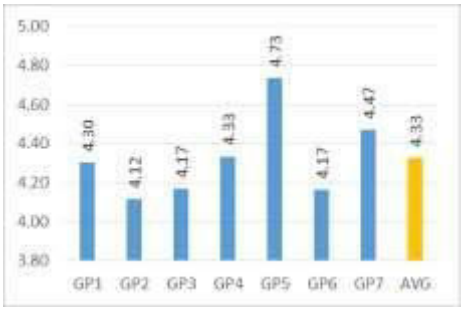

Figure 8: Average marks for Gameplay component

Generally the gameplay component was marked well. Major objections were necessity of displaying elapsed time and real-time track of other players during the whole game process, which reflected in slightly worse marked statement GP2 that average.

5. CONCLUSION

After completing testing and survey we found that Geostep platform can be used in game based learning in interesting and innovative way. Students found first-time experience encouraging and application performed well regardless of phone brand and operating system version.

Few minor problems were observed, mainly concerning positioning and QR code scanning services. Based on participants' suggestions we recognize the need to improve QR code scanning techniques, either by enabling separate scan button that should serve to confirm the scan, or by implementing it in augmented reality.

The testing described in this paper had some limitations, because it was performed during two days with relatively small group of students. Based on overall good results we gained interest and support of some of the faculty's academic staff, so the next step would be implementation and later evaluation of Geostep on multiple courses during the whole semester.

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