# Learning History Through Location-Based Games: The Fortification Gates of the Venetian Walls of the City of Heraklion

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**Abstract.** Games in education have always been a tool for increasing motivation and interest of learners. We present Location-Based Games (LBG) as a tool to involve and motivate students in the learning process. LBGs require the player to move around in order to complete a task and proceed in the storyline and use localization technology such as Global Positioning System (GPS). LBGs are built on physical worlds, while virtual world augmentations enable the interaction of physical and other related (cultural, historical etc.) data with the player. Augmented reality (AR) is used to provide this extra layer with 3D objects, avatars and animations for player's interaction. In our paper we present a history learning LBG with the use of augmented reality in the form of 3D objects. We explore the concept, of having both virtual and physical worlds available within the same visual display environment.

**Keywords:** Game-based learning (GBL) · Location based educational games
Mobile learning · Augmented reality (AR) · Digital storytelling
Education outside the class · Global Positioning System (GPS)

## 1 Introduction

Gaming has always been a fun way to learn new things and acquire skills. Many learning theories align with the gaming process [1]. In games students are highly motivated by involvement with the subject of study and stimulation comes with learning by doing. Gamification applies game elements to real life tasks. In this way, it helps in the behavioral change, improves motivation and enhances engagement [1, 2]. The constructivism theory is embedded in Game- Based learning approach [3].


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Ubiquitous computing [4] which describes the technology and the use of a computer that is not static could be the early foundations of Mobile Computing and Location Based Games. In the middle of the 90 s mixed reality was in attention. In [5] Miligram argues: "The next generation telecommunication environment is envisaged to be one, which will provide an ideal virtual space with [sufficient] reality essential for communication".

The purpose of our game -The Heraklion Fortification Gates- is to provide the means for teaching the history of the Venetian walls of the city of Heraklion (Crete). Every time the players reach one of the nine gates/bastions of the walls, they get notifications to answer questions which are related to the history of that gate. Players visit the Fortification's gates all around the city and get information about them. The game ends when the players have passed all the Gates.

The rest of the paper is structured as follows. Section 2 presents the Background based on findings of the literature review conducted. Section 3 introduces the development of the Heraklion fortification gates game and Sect. 4 concludes the paper.

## 2 Background

With the growth of digital games there was a new academic interest in how gaming could contribute through new perspective in education.

Gamification in Education attempts to harness the power of videogames for motivation and put it into practice at classrooms [6]. Teachers achieve this, by translating the kind of engagement that students experience with games, into an educational context which includes influencing students' behavior and goals of facilitating learning [7]. The localization technology evolvement opens a new way in gaming and furthermore on Game-Based Learning. The arenas are now entire cities for many games [8]. Role-playing games, hunts and searching for treasures are just some of the types of Location Based games [9].

### 2.1 Location Based Games and Augmented Reality

Location Based Games require the player to move around in order to complete a task and proceed further [10]. The basic idea with these games is that the players combine knowledge and physical activities that take place in the real world, especially in sights that are rich in educational value, like historic city centers.

Location Based Games are used for academic and pedagogic reasons. LBGs are ludic games which combine learning with pleasure [8]. The characteristics of such games enforce the ability to involve students into meaningful learning activities indoors and outdoors [11].

Augmented Reality (AR) is a technology that allows people to integrate virtual objects and live data directly on the user's surrounding environment [12]. Since 2000, many articles mention LBGs as the new trend. In the following years, more and more location based and AR applications were developed, especially for mobile equipment. "Pirates!" [13] is one of them, a multi-player game implemented on handheld devices connected in a Wireless Local Area Network (WLAN). The players in "Pirates!" used

the physical environment as the game arena [13]. But there was no accuracy in determining the player's location and this assume limits on designing the game. The development in mobile computing and telecommunication with the global positioning system (GPS) was the next big step towards Location Based services and games. In 2003, the game "Can You See Me Now (CYSMN)" [14] was implemented with GPS technology. Players could move around within the city-arena with a fixed speed, they could see the city map and the position of the other players and they could also communicate with each other using walkie-talkies [14].

To serve the goal of education a game must provide the players-students with new information, or relate their background knowledge with the real world. In this case LBGs can connect digital media and metadata with the locations, cultural objects, monuments etc. for the learning gain [15]. This is consolidated by the fact that people are learning easily when they're combining words, patterns and other media within a structured learning environment, in comparison to the use of mere words according to the Cognitive Theory of Multimedia [16].

Augmented Reality elements and digital mapping can be implemented for the creation of educational material by using information on a geo-location with visual references to digital resources [17]. Virtual content could be anything, 3D scenes or objects, a textual display of the data. Augmented Reality enriches the sensorial perception of a person because she/he can see and hear more than others, and perhaps even touch, smell and taste things that others cannot [12]. The main task of AR in our game is the continuous calculation and replacement of the visual angle, so that the virtual image can be accurately projected on an object. Therefore, AR calculates the distance and orientation from the observation device to the predefined pattern in real world and accurately projects the setup model on that predefined pattern, by using computer vision technology.

The first educational location-based game with augmented reality elements was "Environmental Detectives" [18]. It was created by Massachusetts Institute of Technology (MIT) Teacher Educational Program (TEP) and it was targeted to high school and university students. By using hand-held devices, students investigate outdoors to determine the source of a toxin spill on their campus. Some ways of investigation are by taking interviews with virtual people, conducting environmental measurement simulations and analyzing the data.

Another application is a mobile city game called "Frequency 1550" [19]. It was developed by the Waag Society and helped students to acquire historical knowledge of medieval Amsterdam. An experimental design used 458 students from 20 classes of 5 different schools and its results showed that students who played the game and were engaged in the project gained more knowledge about medieval Amsterdam than those who did not play the game and attended regular projects.

### 2.2 Learning History of Venetian Walls in the Digital Era

The Gates of Heraklion consist a remarkable element of the Venetian Walls of the city. The Venetian Walls are a series of fortifications and defensive walls that surround the center of Heraklion. They are one of the best-preserved fortifications of Europe. Their goal was to protect the coastal city from invaders, fact that is proven by the Siege of Candia that lasted for 21 years (1648–1669) and it is the second longest recorded siege in history.

They were first built by the Byzantines although they started being shaped to the way they look nowadays, after the conquest of the city by the Arabs (Saracenes) in 824. A full reconstruction of the walls took place after the island of Crete fell into Venetian control in 13th century.

Municipality of Heraklion in its application "A Tour of Venetian Candia" for its visitors, the Candia of 1640 is enlivened through a dynamic implementation of a virtual tour [20], allows the user (inhabitant, visitor, educational community) to travel digitally through time and space and draw multileveled and diverse information in Greek and English. As the user moves, the application within the old city limits, through specific routes, the Venetian Candia unfolds in front of his/her eyes. An "experiential" in physical space and real-time tour of the historic town center, through new technologies and photorealistic three-dimensional representations [20].

Another application is "E-Guide to the Modern City" [20], which is a contemporary electronic city tour guide for smart mobile devices where the user can tour the city sights in an attractive aesthetic environment, with many photographs, text and audio tours depending on the interests and time. For guests who do not have enough time for extensive tours, the "top ten" offers the most important sights of the city, while the "automatic audio guide" gives information about the monuments located in their way [20].

The work presented in this paper defers from the above application as it follows the game based learning approach which improves motivation and enhances engagement of the player. Our LBG offers knowledge through a game by searching places and answering questions.

## 3 The Heraklion Fortification Gates LBG

### 3.1 Description of the Game

The "Heraklion Fortification Gates LBG" is a game that gives players the opportunity to explore Heraklion in a playful way.

At first, the game locates the player's position and then gives him or her instructions on how to get to a specific location. During the search of the location, cards with information about the place the player has to go are displayed on the screen. When the player reaches the required area, she/he should scan with her/his smart device this area for a pattern, in order to have the 3D augmented reality object appear on her/his screen. When she/he finds it, a question about the place with four possible answers will appear. After answering the question, the player is prompted to take a selfie and moves on to the next place. At the end of game, the player can see the solutions and find out which of them she/he answered correctly and which wrong and all the selfies she/he took in each stop (see Figs. 3 and 4).

The "Heraklion fortification gates" is a game for smart devices. The few things that players need are a smart device with a camera (smart phone, tablet) and zest for knowledge. Once the game is downloaded into the device, the user can initiate the learning experience by login into the game. After login, the camera of the device is activated and starts reflecting the real surrounding environment as background on the device's screen.


**Fig. 1.** Game graphical presentation & pattern

### 3.2 Implementation

The use of localization technology makes it possible to locate the player's position and display the game elements depending on the location. Our LBG, as all Location Based Games do, builds upon the physical world, and with the addition of a virtual world (AR) it enables the interaction of physical and other related (cultural, historical etc.) data with the player.

For the virtual word in our game we have used Vuforia5 [21] which is an AR Software Development Kit (SDK) for smartphones or other similar mobile device that allows the execution of AR applications into a real-time video obtained from these devices. This software uses the capabilities of the computer vision technology to recognize and make the individual tracking of the objects captured by the video camera in real time.

As basic technology for our game development, we have used the Unity Game Engine [22] which allows the developer to create 2D or 3D games. It combines a design platform with C# or JavaScript code. The outcome can be exported in different platforms.

Furthermore, we have used innovative pedagogical approaches for the learning aspect of our game. We mixed the art of traditional storytelling and the use of multimedia technology and thus compiled digital storytelling. By digital storytelling students can be engaged in deep, meaningful learning and enhance their motivation. Digital storytelling provides students with opportunities to organize information in a more familiar way and echoes their use of technology outside of the classroom [4].

The interaction space of the game is divided into three main areas, which act independently or in combination to each other, depending on the game pattern section and the game storytelling stage. These areas are: (a) the top of the device screen which is a bar with informative data, such as scoring and GPS coordinates (see Figs. 1 and 3)

with no interaction capabilities, (b) the middle area of the device screen, which presents instructions prompting the player to move to the next point of interest and information about these points, and quiz questions and (c) the lower screen area which shows an open layer map which locates the player's position when acting independently and answers to multiple choice questions when acting in combination with the rest of the game screen.

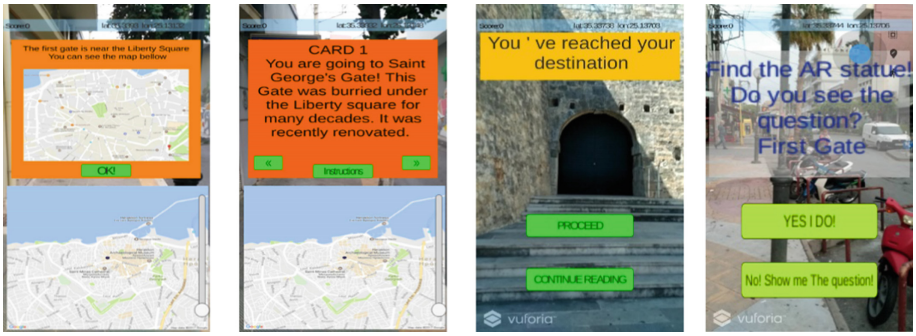


**Fig. 2.** Learning history & locating the point of interest

During the game, the player is notified about the score and coordinates by information which appears on the upper right corner of the screen. As soon as the player is located within the radius of the point of interest, a menu is activated that enables him or her to either proceed to the game flow or continue reading the information cards with the historical data of the point of interest. With the option "PROCEED", the player is encouraged to find the AR element which is a projection of a 3D augmented reality object (see Fig. 2). If the player succeeds on identifying the augmented reality object, a 3D object will be displayed on the screen, and the question will appear in a 3D form. The player then can interact with the 3D AR object by selecting the "YES I DO" option and display possible answers to the quiz question.

In case that the player scans the surrounding place with her/his smart device and cannot locate the 3D augmented reality object, she/he can select the option "NO! Show me the question" and bypass the 3D and AR options of the game. A question in 2D form will appear and simultaneously one mark will be subtracted from her/his game score as a penalty for not locating the AR object.

The scoring scheme of the game is as follows: +1 if the answer is correct, 0 if it is wrong, −1 if the player does not locate the AR object (see Fig. 3).

In every question the player completes, either in a 2D or a 3D question, she/he is asked to take a photograph with the monument and/or the 3D AR object that belong to the point of interest. When the rewarding selfie has been taken the player proceeds to the next point of interest i.e. the next fortification gate of the Heraklion Venetian walls. The map appears again and the steps described above are repeated. By visiting all points of interest, answering all the questions and taking all the rewarding selfies, the game reaches the end. The player is informed with the score, correct and wrong


**Fig. 3.** Quiz with or without AR & player rewarding

answers and receives the certificate which is a compilation of all taken photographs from each point as reward (see right screen shot of Fig. 3).

### 3.3 Player's Position and Game Patterns

Determining players' position and defining the game patterns are important architectural elements, in order to create engaging games. In our game architecture (see Figs. 3 and 4) we thoroughly define those elements and support player positioning and game pattern. In the following paragraphs, we elaborate further these architectural elements.

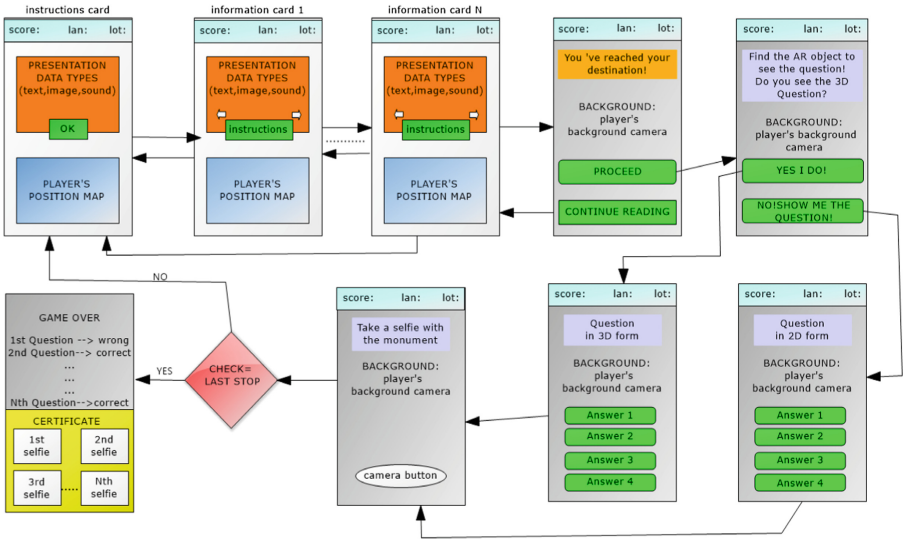


**Fig. 4.** Flow diagram of the game

**Determining player position:** The main problem on Location Based Games is to determine the player's position as more accurate as you can. There are many approaches for doing so, such as: GPS, cell tower triangulation, Wi-Fi, single cell tower and IP. In more detail, Cell- Id is based on geolocating a smartphone [10]. Using the connected cell-tower the mobile telephone provider can locate through the id of the tower. IP geolocating is an interesting approach of determining the position of a mobile device. Although the IP is unique for its device, it changes really fast and furthermore, similar IPs may be used in different places. Other methods use Radio-frequency Identification (RFID) tags to identify smart devices with RFID readers installed, or QR-codes etc. A combination of methods is the best and most accurate way of locating the device, eliminating the environment factor [13].

In our implementation, we use GPS to determine the player's position. GPS is the most popular technology for this scope due to its high accuracy [10]. It consists of a GPS sensor which is discoverable by the GPS satellites. Because of that, it is available everywhere, without the need of a tower cell or any other signals. It is expected to face problems regarding the signal within close spaces, like buildings etc. Another disadvantage is the high energy consumption although many devices nowadays have enough reserve.

**Game Pattern:** Every Location-Based game is built on a pattern, so that the player can use it to move around. "Search and Find" pattern refers to the games that have instructions and guide the players to a specific location. Instead of asking the player to move in specific coordinates, this pattern may let the player find a specific object, such as a monument, a school or a store.

Our game is using this pattern, as it leads the player through the city of Heraklion, so they can find the spots of interest (gates and bastions) and answer the questions. While moving around, the player is presented with useful information about the destination gate in the form of text, mini videos and photos. Figure 4 presents our game flowchart which is according to the game pattern approach. More specifically, the player is provided with instructions as to how she/he will reach the next point of interest. While moving around toward the next location the game provides educational information about the location in the form of text, mini-videos and sound. The player can navigate between information and instruction as she/he pleases until the next point of interest, as shown in the upper row of the flow diagram of Fig. 4. According to our game pattern once the player has reached a point of interest she/he is immediately notified by the game and can decide to look for the AR artifact or not. The decision about the AR artifact affects the interaction elements of the next steps of the game, as presented in rows two and three of Fig. 4. Once the player has played the quiz, she/he is permitted to take a selfie with the AR element at the point of interest, as a reward for achieving an intermediate goal. The above flow of events is repeated until the player visits all points of interest and according to our game pattern, she/he will receive a game certificate, which is an assemblage of all points of interest selfies with the AR elements.

## 4 Conclusion

Location Based Games in education could be the way for producing learning outcomes by increasing the motivation and interest of students about subjects that demand sightseeing. Current handheld devices (smartphones, tablets, etc.) with embedded geolocation technologies and video cameras are ideal medium for such games. Usually, LBG require from the player to move around in order to complete a task and proceed through a storyline. School outdoor activities would be more fun and more pedagogic with the use of LBG adapted in a learning context.

In this paper, we've introduced "The Heraklion Fortification Gates", a LBG that offers to students the opportunity to learn about the history of the Venetians gates of the city of Heraklion. When the student reaches the place of interest she/he gets information about the gate and has to answer to related questions. The game arena is the physical space of the city, while the visual display environment consists of both physical and virtual worlds and augmented reality is used in the form of 3D objects. The structure of the game, the subject matter and the questions involve real historical information resulting adequate educational value and in essence, the game becomes a vehicle that transfers "unseen" information to the player [23].

The new version of the game would have a background scenario for leading the player from place to place. Also a story, perhaps a crime-solving story, that lead the game-flow could make the LBG more ludic and increase further the interest of the players.

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