Supporting the Development and Management of Learning Experiences in Location-Based Mobile Games

The EVANDE project

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Abstract— **Mobile location-based games, exploiting the unique capabilities of mobile devices, such as camera, GPS and compass, can have high learning potential. On one hand, they present a very attractive form of learning for modern students, even very young ones, who have already developed their skills in computer games and are very familiar with the use of mobile devices. On the other hand, location-based games provide a unique opportunity for education since they connect an area with a story, and their activities may result in social, experiential and situated learning. These characteristics can make them a powerful tool in a number of applications, including education, nature and museum exploration, city sightseeing, natural disasters awareness and prevention training. In this paper, we present the design and implementation of PlayLearn, a platform for the development and management of learning experiences in mobile location-based games, consisting of: (a) an authoring tool, supporting the creation and management of games, scenario editing, user interface customization and organization of gaming activities, and (b) a mobile application, compatible with most state-of-the-art mobile devices and platforms, supporting the play of games created by the authoring tool. Our implementation supports the Experience API, allowing the activities that happen as part of gaming (learning) experiences to be recorded, tracked and shared in a Learning Record Store. PlayLearn is part of the EVANDE (Enhancing Volunteer Awareness and education against Natural Disasters through E-learning) project learning infrastructure used for the development of mobile games for the training of civil protection volunteers and local authorities' staff.**

Keywords- mobile educational games; location-based games; learning experiences; experiential learning.

I. INTRODUCTION

Location-based services on mobile phones have become very popular in recent years. These services have been developed to provide location-based information to the user. This information derived from the location-based-services can be used in entertainment and education to create games that use the geographical location of the user or other people as an essential part of the game [1]. A -so called- mobile location-based-game [2] is a type of pervasive game in which the game-play evolves and progresses via a player's location. Thus, mobile location-based games must provide some mechanism to allow the player to report their location. Frequently, this is performed by some kind of localization technology, e.g., by using satellite positioning through GPS. The difference between a video game and a location-based game focusing on the same story is that the later has a closer connection between game and reality.

In terms of the main objective, mobile location-based games may be categorized as games that are created for fun, for learning or for mixed objectives [3]. All these categories of games seem to have a higher learning potential. On the one hand, modern students, even very young ones, have already developed skills in computer games and are very familiar with the use of mobile devices, and educational mobile games can provide a very attractive form of learning for them. On the other hand, the location-based games provide a unique opportunity for education since they connect a geographic area or object with a story. The physical and cultural surroundings are an integral part of the game space, and the location of the gamers is a key aspect of the game-playing activity. By visiting the actual locations, the story becomes more authentic and therefore leads to better educational results. Essentially, the games of this kind allow the user to collect data from the real world and assign them to the game's map. De Souza et al. [4] have observed that these activities produce learning that is social, experiential and situated. The combination of informal learning and mobile outdoor games can be seen as a relevant arena for conducting novel learning activities that involve learners in different tasks including physical motion, problem solving, inquiry and collaboration [5].

Learning experiences are those events and activities from which we learn by experience and can identify, to a certain extent, what we have learned. Different Learners have different characteristics and preferences (e.g., learning style, educational level, background knowledge etc.) and these affect how these learning experiences might be organized in terms of their activities as well as the learning material that should support those activities to achieve specific goals [6].

Experiential learning, according to Kolb [7], can exist without a teacher and relates solely to the meaning-making process of the individual's direct experience. Knowledge is continuously gained through both personal and environmental experiences.

The Experience API (xAPI) is an eLearning software specification that allows learning content and systems to speak to each other in a manner that records and tracks all types of learning experiences [8]. The results of learning experiences are stored in a Learning Record Store (LRS), which may exist in a traditional Learning Management System (LMS), or on its own (installed or web-based). xAPI does not require a learning experience to take place in any particular medium (mobile, desktop, tablet), offline or online, or in any particular system. By collecting and analyzing xAPI for a specific learner, a picture of the learner's activities, achievements, competencies and interests can be created, drawing on experiences using multiple devices and multiple activities [9]. Exposing data through the xAPI provides a means for interoperability but also allows for innovation of learning content, experiences, and systems, something that is not easily afforded in the current learning model [10].

The use of xAPI with mobile devices is a powerful combination which can leverage learning, since it enables opportunities for capturing the activities from diverse learning experiences that take place exploiting the unique capabilities of the mobile platform for learning, such as the mobile phone's camera, GPS and compass. This may lead to new kinds of learning experiences and a much wider adoption of mobile-based performance support [10]. For instance, if a learning design was predicated on students taking pictures of examples of a particular phenomenon, and then sharing and discussing these with other students, the xAPI enables the various activities in this learning design to be recorded and tracked in an LRS in the form of activity streams. Later, the teacher could retrieve this information from the LRS, initiate a discussion with the students in the class, or even improve the learning design of the game according to the results to fit better the needs of the learners and learning context. These are only some of the many uses and benefits of adopting xAPI to track and share learning experiences.

In this paper, we present the design and implementation of PlayLearn, a platform for the management of learning experiences in location-based mobile games. The games supported follow a flexible model, allowing our framework to support a wide variety of games in various applications. The platform consists of: (a) an authoring tool (web application) supporting the creation and management of mobile location-based games, including scenario editing, user interface customization and organization of gaming activities, and (b) a player application (mobile application) for supporting the play of games created using the authoring tool. The player application is compatible with most state-of-the-art mobile devices/platforms, while both tools have been designed with flexibility and extensibility in mind. Moreover, our implementation supports the Experience API (xAPI), allowing the activities that happen as part of the gaming (learning) experiences to be recorded, tracked and shared in a Learning Record Store (LRS).

PlayLearn is part of EVANDE project learning infrastructure. EVANDE (Enhancing Volunteer Awareness and education against Natural Disasters through E-learning) [11] is a European project co-funded under the Union Civil Protection Mechanism. It aims to create a new learning tool to train civil protection volunteers and local authorities' staff on the topics of floods, forest fires, earthquakes and European civil protection policies through the identification of best practices and knowledge, the development an e-learning platform and tools to host e-learning courses, games and training activities, as well as the organization and implementation of local-based dissemination and training actions. Two piloting e-games based on mobile devices (e.g., tablets, mobile smart phones) are being developed within the framework of the European project. One of them is presented in detail in this paper.

The structure of the rest of this paper is as follows: Section II presents systems and research related to this work. Section III specifies the model for describing educational games. Section IV presents the architecture that has been designed and implemented, while Section V provides some more insight on the implementation of the platform. Section VI introduces EVANDE project and describes in detail how this framework and infrastructure is used for the creation and management of mobile games for the training of civil protection volunteers and local authorities' staff presenting one of the two main piloting game scenarios developed. Finally, Section VII summarizes and reviews the presented work and sketches some perspectives for future extensions.

II. RELATED WORK

Various types of location-based games and platforms have extensively been reported by several authors, such as in [3] and [5]. In this section, we are focusing on those that are closer to our work.

Geocaching [12] is an outdoor activity where players try either to find hidden caches using GPS coordinates, or hide their own caches and register their location. Activities are supported by: (a) a desktop application enabling the searching, filtering and previewing of geocaches, as well as (b) a mobile application that in addition to the previous features provides basic navigational assistance. Geocaching applications support strictly basic treasure hunt outdoor activities without providing in depth game experience. On the contrary, PlayLearn provides a game authoring tool and a player application supporting different game types based on a great variety of activities that can be either bounded or not to specific locations. Using our tools, the user is able to create his own game, share it and play it with others. Furthermore, we provide the capability to organize location based events allowing the participants to have a real in depth gaming experience either by competing or cooperating.

WHAIWHAI [13] is an interactive story based on a gaming platform and developed to offer a way of exploring the less touristic and unknown city places. Players are supposed to walk the city, collect clues, answer enigmas and discover popular and traditional tales. Although games are

customizable in terms of difficulty, time limit and number of players, WHAIWHAI is limited to exploration activities. On the contrary, PlayLearn provides tools and services for creating and playing various types of games, exploited under different contexts and targeting users of certain age groups.

Tourality [14] is a location-based game where the user's main goal is to visit several predefined spots of certain interest. In multiplayer mode, the game focuses on time, requiring the user to be faster than the others, maintain a high score and compete either by participating in a team or alone. Although Tourality enhances competitiveness and cooperation, it focuses strictly to these characteristics leaving aside any in depth educational activity that a game may provide. On the contrary, using PlayLearn a user is able to create different games consisted of a variety of educational activities based on specific user profiles. By doing so, the player of these games, apart from visiting a set of specific places, is able to browse educational material of different types (video, image, sound, text), answer riddles, perform metadata annotation tasks, search for hidden treasures, get rewards etc.

AnswerTree [15] is a collaborative mobile location-based educational game designed to teach 8-12 year old players about trees and wildlife. The game is designed around collecting virtual information cards about notable trees by answering questions. Collaboration is encouraged by the fact that solutions to these questions are obtainable through sharing knowledge with other cardholders. Apart from this, AnswerTree is a static game targeting users of specific profile, interests and goals. On the other hand, using PlayLearn users are able to achieve the same goals while having the opportunity to extend their game (either by creating their own educational activities or selecting from a broad set of preexisting ones), personalize the user interface and organize events.

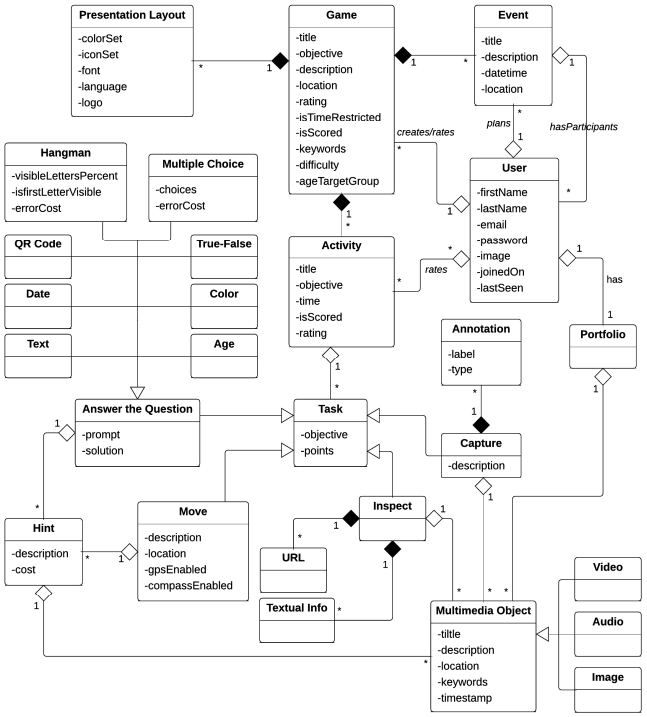


Figure 1. PlayLearn core model

ARIS [16] is a platform for creating and playing mobile games, tours and interactive stories and it is considered the most relevant work compared to ours. Its authoring tool is available as desktop application and provides the ability to specify the game location, create quests and upload multimedia files. Apart from these features, it does not provide any functionality for organizing gaming events focused on player profiles, and unlike PlayLearn's authoring application, the game creator cannot customize the user interface of the game. Another important limitation is that ARIS game player application is designed as a mobile application available only for iPhones. On the contrary, we provide a game player for the majority of mobile phone operating systems including iOS, Android and Windows. Additionally, PlayLearn's game player application is also available through the browser.

III. MODEL

The model developed and supported by the PlayLearn platform for the creation of location-based educational games has been designed with flexibility and extensibility in mind, to be able to describe as many as possible different types of games. Figure 1 presents the core model entities in the form of a class diagram.

The *Users* of the system include both game creators and players, differentiating based on their role. The *Game* class represents the games which can be created, managed and played by *Users* using PlayLearn. A *Game* has a goal and consists of several descriptive and presentation metadata, while it is possible for the creator to adapt its *Presentation Layout* (e.g., color set, icon set, fonts, language, logo, etc). A *Game* consists of a sequence of *Activities* with certain objectives that have to be tackled by the player to support the game goal. *Activities* consist of *Tasks* which are considered as the actions to be performed in order to achieve the respective activities' objectives. There are currently four types of *Tasks*:

- *Move* is a type of Task in which the user needs to navigate in order to reach a specific destination.
- *Inspect* is a type of Task in which the user has to read a text document, apothegm or any other piece of information in textual form (*Textual Information*), or view an image/video and listen to a sound (*Multimedia Object*).
- *Answer the Question* is a type of task in which the user should provide an answer for a given question. The type of the question can be of many types, including *Multiple Choice, True – False, Text* (the player should provide his answer in plain text), *Hangman* (the player needs to find a hidden word), *QR Code* (the player scans a pattern code, after searching for it in a specified location range), etc.
- *Capture* is a type of task in which the user has to record a video, take a photo, or record a sound. It can

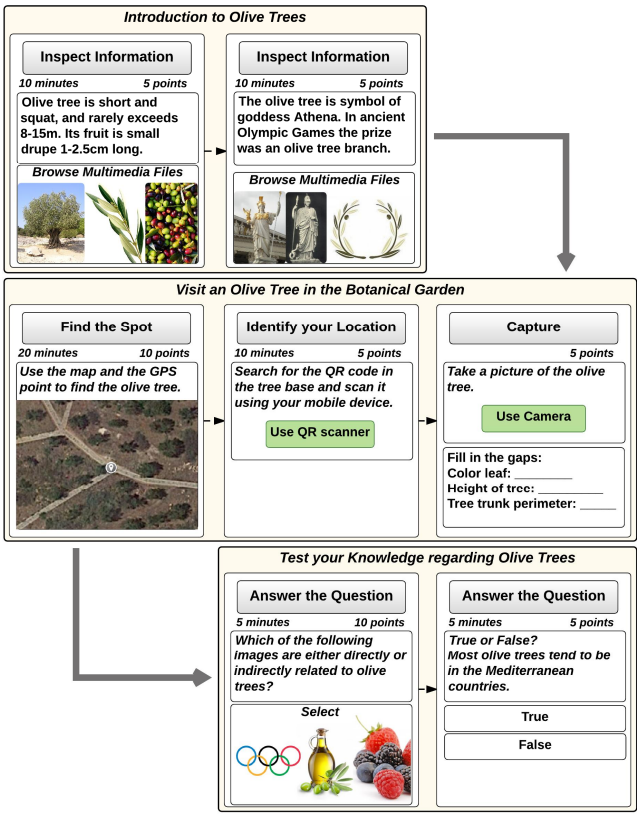


Figure 2. A simple game example for a visit to a Botanical garden to explore olive trees, consisting of three activities corresponding to the pre-visit, visit and post-visit phases

be extended to require the *Annotation* of the captured *Multimedia Object* with metadata.

The *Multimedia Object* class represents multimedia objects of type: video, image, text, and audio. Each type of Multimedia Object is depicted as a different class, holding its own descriptive attributes. The *Audio* class represents the multimedia objects of type sound. Optionally, it contains a GPS point specifying the location that has been recorded. The *Image* class represents the multimedia objects that are of type image. Optionally, it contains a GPS point with information about the location where it was captured, as well as other descriptive metadata. The *Video* class represents the multimedia objects that are of type video. Optionally, it contains a list of GPS points with information about the location where it was recorded, as well as any other information provided by the camera. The list of GPS points can be used to recreate the path that the user took for the duration of the capturing. Each User has a *Portfolio* that corresponds to a library with *Multimedia Objects*, which are used in games creation.

Games can be used for the organization of gaming *Events*, which can be created and shared by *Users* in order to promote gaming activities in certain locations. Each *Event* may refer to a specific game, location and date/time. Additionally, the list of the event participants can be either open or restricted to specific user groups. Since Games can be bounded to a specific place, such information along with

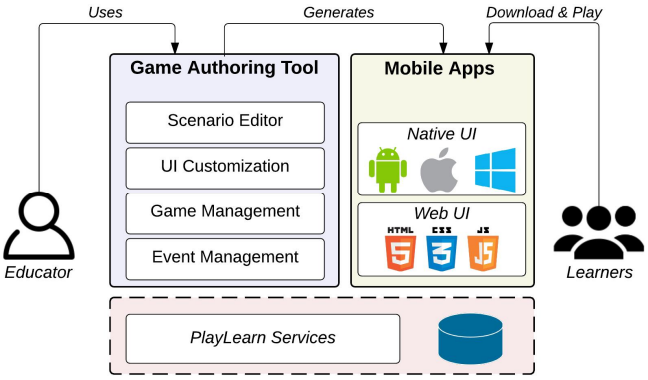


Figure 3. PlayLearn conceptual architecture

game classification, target group, rating and difficulty can be used for game searching and filtering.

Figure 2 presents a simple game example for a visit of preliminary school pupils to a Botanical garden to explore olive trees, consisting of three activities corresponding to the pre-visit, visit and post-visit phases.

IV. ARCHITECTURE

Built as a web application, the system adopts the Rich Internet Application (RIA) principles, which promote the development of web applications as desktop applications performing business logic operations on the server side, as well as on the client side. The client side logic operates within the web browser running on a user's local computer, while the server side logic operates on the web server hosting the application.

Figure 3 presents the conceptual architecture of the PlayLearn platform. The main parts of this architecture are: (a) The Game Authoring Tool used by the Educator for the creation of games, providing functionality for game scenario design, game and event management, and UI customization, and (b) the Mobile Apps providing both Native UI to support mobile devices with different OS (Android, iOS, Windows) and a Web UI, which are used by the Learners to download and play the games created by the Authoring Tool during events organized by the Educators. The Game Authoring Tool and the Mobile Apps are supported by a number of services and repositories that are described in detail in the following paragraphs.

The overall system architecture is presented in Figure 4. For the development of the application we adopted several design patterns [17]. The use of well-established and documented design patterns speeds up the development process, since they provide reusable solutions to the most common software design problems [18][19]. The Model-View-Controller (MVC) design pattern [20][21] and the Observer pattern were used on the client side, and a multi-tier architecture was implemented on the server side, which are described in the following sections.

A. Server Side

The Server Side part of our platform adopts a multi-layered architectural pattern consisting of three basic layers

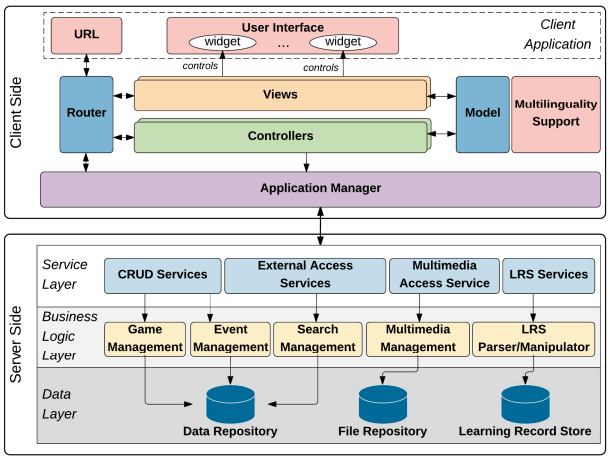


Figure 4. PlayLearn system architecture

(Figure 4): The *Service Layer*, the *Business Logic Layer* and the *Data Layer*. This increases the system's maintainability, reusability of the components, scalability, robustness, and security.

The *Service Layer* controls the communication between the client-side logic and the server-side logic, by exposing a set of services (operations) to the client-side components [22]. These services comprise the middle-ware concealing the application business logic from the client and have been built as RESTful [23][24]. The basic system services are:

- *CRUD Services*, facilitating the creation, retrieval, update and deletion of a game, an event associated with a game, a user etc.
- *External Access Services*, providing the means for the client side and external systems to use the data of the system.
- *Multimedia Access Services*, enabling access to the uploaded multimedia files and their respective thumbnails, and
- *LRS Services*, facilitating the creation of statements. A Learning Record Store (LRS) is a place to store learning records and is connected with the xAPI. As xAPI-enabled activities generate statements, they're sent to an LRS. The LRS is simply a repository for learning records that can be accessed by a Learning Management System (LMS) or a reporting tool.

The *Business Logic Layer*, also known as *Domain Layer*, contains the business logic of the application and separates it from the Data Layer and the Service Layer. In more detail:

- The *Game Management Module* is responsible for the game management, as well as for the activity and task (de)composition in our system.
- The *Event Management Module* is responsible for the event management.
- The *Search Management Module* handles the search and filter queries posed on our dataset and delivers the obtained results to the appropriate component of the Service Layer.
- The *Multimedia Management Module* is responsible for managing the persistence and serving of multimedia files, as well as for performing basic metadata extraction and thumbnail generation.
- The *LRS Parser/Manipulator Module* is responsible for the persistence and accessing of gaming results that have been collected and obtained during a gaming activity.

The *Data Layer* accommodates external systems which are used to index and persist both data and multimedia files. Such systems are:

- The *Data Repository*, storing all the data of the system,
- the *File Repository*, persisting the multimedia files and thumbnails, and
- the *Learning Record Store*, archiving the collected results of the gaming activities which have been already performed.

B. Client Side

The Client Side of the PlayLearn applications is responsible for the interaction with the user. It refers to both the authoring tool (web application) and the player application (mobile application). All the actions performed by an individual are handled by the client side logic which undertakes the presentation of the information as well as the communication with the server. In order to achieve a high level of decoupling between the components forming the client logic we adopted the Model View Controller (MVC) design pattern, as well as the Observer pattern. The usage of the MVC pattern introduces the separation of the responsibilities for the visual display and the event handling behavior into different entities, named respectively, View and Controller.

The *Model* refers to the business objects which are being used by our system. When the system needs to present information about a business object, the client side requests the respective information from the server side using the services that the later exposes. Similarly, when an update on the Model needs to be persisted, the client side sends the updated Model to the server side, triggering the indexing and storage of the business objects by the appropriate modules and external systems.

The *Views* are responsible for the presentation of information in the user interface. Each view controls a number of widgets on the application's graphical user interface. It consists of several handlers that are responsible for listening user actions, as well as HTML templates that define the presentation of the widgets.

The *Controllers* are the modules that respond to the user input and interact with the Views in order to perform any change on the user interface. Furthermore, they maintain the Model and change it appropriately. Every View has a dedicated Controller managing, handling and propagating any changes that are to be performed or have already been performed to the user interface. Moreover, there are several cases where a "composite" Controller manages a number of other Controllers in order to create complex widgets.

The Router is used for deep-linking URLs to controllers and views. It manages the URL of the client browsers,

providing a different path to each distinct interface, without raising a browser event that will force a reload on the whole page. When the URL changes the Router analyzes the new path and handles the transition to the new View. This is performed using mappings between the different URLs supported in the system, the Controllers and the Views.

The *Multilinguality Support* module manages the translation of the user interface elements through the use of certain configuration files. The process is easily adaptable and the system can be extended to support any language with minimum effort. It is worth to mention that currently the graphical user interfaces of the system have been already translated in English and Greek.

V. IMPLEMENTATION

The PlayLearn platform has been successfully implemented as described in the previous sections. Its server side is based on Java and makes extensive use of the Spring Framework in order to tackle certain backend aspects like data access. For persistency storage, MongoDB is used. One of the reasons that led us to choose MongoDB is that most of our data does not conform to a rigid relational schema. Hence, we cannot bind it in the structure of a relational database and we need some more flexibility. Due to the fact that MongoDB allows us to store parts of our data in different forms with minor effort, our back end is considered compatible with the Learning Record Store and xAPI. Moreover, this makes our system capable of supporting interoperability with other external systems with minimum effort.

Regarding the client side, both the game authoring tool and the player application are based on the latest web-application standards, rely on the JavaScript programming language and make extensive use of the AngularJS framework. Moreover, they have been created in order to match different user requirements, and thus their user interfaces are implemented differently in order to match the goals of their stakeholders. Apart from JavaScript, the user interface layout has been built using HTML5 and CSS3. The player application has been packaged as a native mobile application with the use of Phonegap, making it compatible with all the major mobile platforms. This allows our application to run without the need of internet access, or loading its source each time that the user accesses it. Additionally, the use of Apache Cordova allowed us to provide more functionality by using various native platform features that are otherwise unavailable to web applications.

Figure 5 presents the graphical user interface of the game authoring tool. More specifically, it shows the use of the scenario editor while the user creates a new task of type "Capture" in order to populate an already existing activity of a game named "Explore Olive Trees". The left side of the user interface is used for presenting the game activity list, while the right side is used as the main working area for customizing activity tasks. The top bar is used for the main menu inspection, user interface customization (in terms of language and layout), as well as for changing personal settings. Figure 6 presents the graphical user interface of the

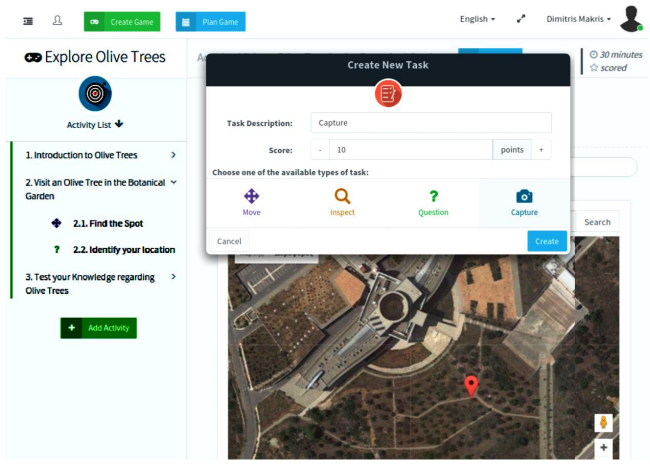


Figure 5. Game authoring tool (web application)

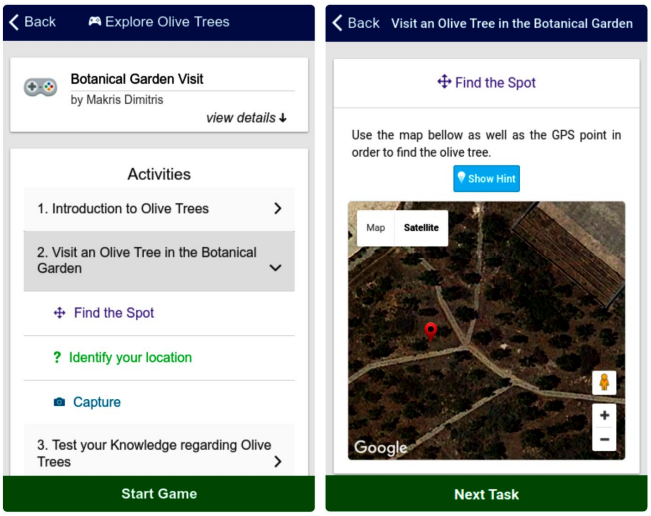


Figure 6. Player application (mobile application)

mobile application that was generated by the game authoring tool in Figure 5. The screenshot on the left side shows the preview that is presented to the user just before starting the game. It includes basic information such as the event, the game, the creator and the list of activities that need to be completed. On the other hand, the screenshot on the right has been taken during playing the game and shows an activity task of type "Move" requiring the user to use the map in order to navigate to a specific spot of interest.

VI. GAMES DEVELOPMENT IN EVANDE PROJECT

The Laboratory of Distributed Multimedia Information Systems and Applications at the Technical University of Crete (TUC/MUSIC), the developer of PlayLearn, is collaborating with the Natural History Museum of Crete (NHMC) in order to develop and run two piloting e-games based on mobile devices (e.g., tablets, mobile smart phones) within the framework of the European project EVANDE. EVANDE (Enhancing Volunteer Awareness and education

against Natural Disasters through E-learning) [11] is a European project co-funded by the European Union Civil Protection Mechanism (Grant Agreement No. ECHO/SUB/2014/693261). EVANDE is targeting to the training of civil protection volunteers and local authorities' staff on the topics of floods, forest fires, earthquakes and European civil protection policies. Additionally, the EVANDE project aims at the exchange of experiences in order to strengthen the cross-border collaboration and effectiveness of civil protection policies and activities among the participating countries and the involved target groups.

The EVANDE project (2015-2016) is coordinated by the Natural History Museum of Crete-University of Crete, in Greece and involves also the following partners:

- Technical University of Crete - Laboratory of Distributed Multimedia Information Systems and Applications, GREECE
- Consorci De La Ribera, SPAIN
- Beigua European & Global Geopark, ITALY
- Earthquake Planning & Protection Organisation, GREECE
- Fondazione Hallgarten – Franhetti/Centro Studi e Formazione Villa Montesca, ITALY
- Centre for Educational Initiatives, BULGARIA

Several activities are developed by EVANDE project. Besides mobile games, these activities also include the publication of technical reports on natural hazards, the European civil protection policies and best practices and the organization of an international volunteers' meeting in Italy.

Among the main outcomes of the EVANDE project, the development of an e-learning platform [25] is also included, to train local authorities' staff and civil protection volunteers on floods, forest fires, earthquakes and European civil protection policies. The e-learning courses are free of charge and require only a simple registration.

A. Education and Public Awareness in Natural History Museum of Crete

The Natural History Museum of Crete (NHMC) (nhmc.uoc.gr) is a pioneer institute at national and European level in the study and management of the natural environment, in public awareness, education and sensibilisation of local people as well as visitors from abroad through its Centre of Environmental Training (NHMC-CET), in linking university activities with the Society and is also involved in the set-up of a network of Ecological Museums. In its permanent Exhibition Halls, of 3500 m2, in the city of Heraklion, Crete, the natural environment of the eastern Mediterranean area with special emphasis on Greece and Crete is displayed.

Combining its scientific and educational knowledge, NHMC pursues special interest in Integrated Learning Strategy Plan for the active diffusion of the knowledge accumulated to all sectors of the society. More specifically, Education and Learning in NHMC follow 5 strategic poles: a) Bridging NHMC with Formal and Informal Education: 36 educational workshops for school groups connect NHMC with school curricula and families, using Inquiry-based learning, theatrical games, creative manufacturing, observation exercises, field trips, ICT games etc.; b) Life Long Learning: in NHMC-CET, more than 4000 teachers and other professionals have been trained on Environmental and Pedagogical issues. All training courses have been Quality assured and Validated; c) Volunteering: members of the club "Friends of the NHMC" participate in several indoor and outdoor activities; d) Awareness of People with Special Needs: specialized workshops take place; e) Editions: educational packages for Eastern Mediterranean natural environment are produced.

Most of the educational and public awareness activities are carried out into NHMC permanent Exhibition Halls, where the NHMC Centre for Environmental Training (NHMC-CET) is also activated.

B. EVANDE mobile games

Promoting exploration with mobile location-based educational games is vital to be able to teach players knowledge about specific areas where a crisis can happen [26]. A location-based game provides a low-cost solution for promoting exploration, as it can easily be extended to any area. Due to their nature, mobile location-based games comprise a powerful learning tool in study and awareness of the nature, characteristics and evolution of physical phenomena and practicing on the field on best practices and strategies to prevent and respond on the most effective manner, benefiting the maximum from human and technical resources. For example, a vital part of understanding the risks of an earthquake or flood event is to have knowledge of one's local area. In an evacuation scenario, knowing where it is safe to go is important. Training on these issues is among the main topics covered by the EVANDE project.

The mobile games produced in the context of EVANDE project aim to test innovative methods for the training of civil protection volunteers and local authorities' staff, through the use of new technologies. In addition, they aim to enrich all the educational activities of the NHMC offered to schools, families, local and international visitors.

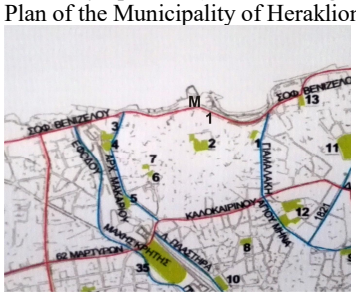
One of the game scenarios developed aims to simulate an earthquake drill. In this scenario, players (civil protection volunteers or local authorities' staff working in civil protection) are supposed to act as rescuers that have the task of saving a family trapped in the Exhibition Halls of the NHMC during an earthquake. They are given information about the escape map of the NHMC and the assembly outdoor points that are defined by the local civil protection emergency plans. They need to select their protective and rescuing equipment and take virtual decisions during the unexpected virtual incidents they face in their rescue operation. The aim of the unexpected incidents is to test the knowledge of players and encourage their critical thinking and team work. An indicative example of an unexpected incident that the e-game includes is the case of an injured person that interrupts the normal rescuing operation of the family. Once the players manage to rescue the people in need (the family and the injured person) they have to reach an

outdoor assembly point to avoid the risk of tsunami that might appear during the virtual earthquake. The exact game scenario is presented in detail in Table I. As a result of this e-game scenario, players familiarize themselves with rescue operations and problems and gain knowledge on the real assembly points of their local emergency plans.

NHMC's facilitators will have the chance after the end of the e-game to reflect with players on civil protection guidelines and preparedness measures. Players can share with NHMC's staff their experience with rescue operations and define the existing challenges and the proposals for improvement of the drills or the local emergency plans. In addition, the conclusions of the piloting operation can be used for the planning of follow-up activities in the framework of the wider educational programs of the NHMC.

TABLE I. A GAME SCENARIO SIMULATING AN EARTHQUAKE DRILL

Game title	Rescuing a family and accompanying it to the assembly point defined by the evacuation plan/local emergency plan of Heraklion of the Municipality of Heraklion
Game goal	There is a strong earthquake happening during the visit of a family to "Ereunotopos" in the NHMC. As a result, a mother and a child are trapped in the night camping space of "Ereunotopos" due to the fall of the ceiling. The persons are still safe and sound however they can't walk, according to the information that the emergency base station has. The player needs to provide first aid to the family and accompany it to the assembly point outdoors, near to the NHMC.
Locations where the activities of the game will take place	**Point 1:** Base floor, entrance of the NHMC, virtual emergency base station **(Starting point)** **Point 2:** Stares connecting the outdoor yard (-1 floor) with the main street**Point 3:** Lift **Point 4:** Night camping space ("Ereunotopos"), Exhibition halls of the NHMC, where the family is. An injured person is also there. (-1 floor). **Point 5:** Emergency exit the outdoor yard (-1 floor) **Point 6:** Assembly point (outdoor space between the 3rd Elementary School and the Church of Agia Triada) **(Ending point)**
Time restriction/Time available to perform the game	No time restriction
Information about the score to be achieved by the winner	Players gain 1 point if they reply correctly to some questions.

ACTIVITY 1 Players' preparation (informing players about their tasks, the equipment they need to take, the NHMC emergency (evacuation) plan, the Evacuation Plan with Assembly points as defined by the Local Emergency Plan of the Municipality of Heraklion)			
Location	**Task type**	**Task description**	**Score**
Point 1	**Inspect**	You have to locate the mother with the child who are trapped in "Ereunotopos" (-1 floor), provide them with fist aid and accompany them to the most suitable assembly point of the Municipality of Heraklion. Before starting, you should get informed about the NHMC's emergency (evacuation) plan, the Evacuation Plan with Assembly points as defined by the Local Emergency Plan of the Municipality of Heraklion) and take your equipment from the base station.	
Point 1	**Inspect**	Emergency and Evacuation Plan with Assembly points (Local Emergency Plan of the Municipality of Heraklion). 	
Point 1	**Answer the question (multi choice)**	Choose the most suitable set of equipment: 1. Helmet, phosphoric jacket, torch, whistle, first aid box, wireless communication equipment, emergency and evacuations plan in printed version (CORRECT), 2. Combat boots, torch, gloves, first aid box, emergency and evacuations plan in printed version (WRONG)	1
Point 1	**Inspect**	You took your equipment and you are ready to start your mission! In the middle of your route you will find QR codes that you need to scan in order to confirm if your route is correct and in line with the emergency/evacuation plan.	
Point 1	**Move**	Move towards the -1 floor where "Ereunotopos" and the family are.	
ACTIVITY 2 Locating the trapped family, provision of first aid to the family, accompanying the family to the assembly point outdoors, exit from the "Ereunotopos"			
Point 2 or Point 3	**Answer the question (QR code)**	Did I choose the right way to move from one floor to the other? Scan the QR code. 1. If player is at stares - **Point 2** (CORRECT) *QR code text:* Yes. In the cases of the earthquakes we don't use the lift. There is danger to be trapped there. 2. If player is at the lift - **Point 3** (WRONG) *QR code text:* No. Your selection was wrong. There is danger to be trapped in the lift. Go to the stairs **(Point 2).**	1
Point 2	**Move**	Continue your route from the stairs (**Point 2**) to the night camping site in	

		"Ereunotopos", where the family is (**Point 4**, -1 floor).	
Point 4	**Answer the question (QR code)**	Find the QR code and scan it in order to confirm that you arrived at the right place. *QR code text:* You arrived at the right place.	
Point 4	**Inspect**	You just arrived but you see there is an injured person that can't walk.	
Point 4	**Answer the question (multi choice)**	What do you do in such case? Choose the correct answer. 1. I provide the first aids to the injured person and to the family and accompany all to the assembly station. (WRONG) 2. I inform the emergency base station about the injured person. I provide the first aids to the injured person but continue my route with the family in order to rescue them. (CORRECT)	1
Point 4	**Move**	Continue your route from "Ereunotopos" (**Point 4**) to the assembly place through the emergency exit door (**Point 5**).	
Point 5	**Answer the question (QR code)**	Find the QR code and scan it to confirm that you selected the right emergency exit door (**Point 5**). *QR code text:* You have selected the right emergency exit door.	
ACTIVITY 3 Choosing the safest assembly point according to the guidelines of the Institute of Geodynamics (after you exit from the NHCM) .			
Point 5	**Inspect**	The Institute of Geodynamics issued guidelines due to a possible tsunami caused by the earthquake. In case of tsunami, people must distance themselves from the coast, due to the difficulty in predicting the wave high.	
Point 5	**Answer the question (multi choice)**	Which Assembly Point is the most suitable according to the guidelines of the Institute of Geodynamics? 1. Playground of Bodosakeio School. (WRONG) 2. Outdoor space between the 3rd Elementary School and the Church of Agia Triada. (CORRECT)	1
Point 5	**Move**	Move to the Assembly Point of the outdoor space between the 3rd Elementary School and the Church of Agia Triada (**Point 6)** (*The GPS and an interactive map are used to help the player reach the destination*)	
Point 6	**Answer the question (QR code)**	Find the QR code and scan it in order to confirm that you reached the Assembly Point of the outdoor space between the 3rd Elementary School and the Church of Agia Triada. *QR code text:* You are at the right place. You reached the Assembly Point between the 3rd Elementary School and the Church of Agia Triada.	
Point 6	**Inspect**	The outdoor space between the 3rd Elementary School and the Church of Agia Triada is the best option between the two assembly points because is more distant from the coast. When there is a tsunami risk, you have to distance yourself from the coast, as much as possible.	
Point 6	**Inspect**	Congratulations! You completed your mission. Press next to see your score and end the game.	

VII. CONCLUSIONS

In this paper, we presented the design and implementation of PlayLearn, a platform for the development and management of learning experiences in location-based games. PlayLearn provides an authoring tool (web application) supporting the creation and management of mobile location-based games, including scenario editing, user interface customization and organization of gaming activities, and a player application (mobile application) supporting the play of games that have been created using our authoring tool. The PlayLearn's player application is compatible with most state-of-the-art mobile devices/platforms, while both tools have been designed with flexibility and extensibility in mind. The underlying model supports a great variety of basic building blocks that can be exploited by a user in order to create a great range of complex and structured location-based gaming experiences. The activities that happen as part of these gaming (learning) experiences are recorded, tracked and shared in a Learning Record Store (LRS) by supporting xAPI. Both applications have been evaluated for their usability through the use of pluralistic walkthroughs and extensive paper prototyping.

PlayLearn is part of the EVANDE project learning infrastructure used for the development of mobile games for the training of civil protection volunteers and local authorities' staff. The pilot testing of the mobile games developed during the EVANDE project can lead to their improvement for wider use in the future, ensuring the follow up of the project. More specifically, these e-games: a) could be combined with other civil protection educational tools developed by the NHMC within the frames of previous and running European civil protection projects, such as PATCH (ECHO 070401/2009/540426/SUB/A4) [27], RACCE (EU, Civil Protection Financial Instrument, 070401/2010/579066 /SUB/C4) [28], SEE (ECHO/SUB/2012/638511) [29], CPMODEL (ECHO/SUB/2014/693249) [30], EPRES (ECHO/SUB/2014/698447) [31], etc.) and b) could be integrated with several educational programmes and/or pathways implemented for school groups, families and individual visitors, such as "I am protected by the seismic danger", etc.

In terms of the technical infrastructure, our future plans also include the following: (a) direct connection with repositories persisting observational data like GBIF, BioCASE and Natural Europe [32], in order to easily enrich the educational content of a game, (b) direct connection with well known cultural heritage repositories like Europeana [33], and (c) enabling the creation of observations during the

play of a game [34], as well as their further dissemination to related repositories.

ACKNOWLEDGMENT

The work presented in this paper is partially funded in the scope of the EVANDE (Enhancing Volunteer Awareness and education against Natural Disasters through E-learning) project co-funded under the Union Civil Protection Mechanism, Grant Agreement No. ECHO/SUB/2014/693261.

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