To be or not to be in situ outdoors, and other implications for design and implementation, in geolocated mobile learning

Patricia Santos, Davinia Hernández-Leo and Josep Blat
ICT Department, Universitat Pompeu Fabra, C/Roc Boronat 138, 08018 Barcelona, Spain
Tel. 0034 935421428
{patricia.santos, davinia.hernandez, josep.blat}@upf.edu

ABSTRACT

Fostering contextual learning in situ outdoors is one of the main opportunities favoured by mobile computing. Of particular interest is the application of the Global Positioning Service (GPS) to geolocate educational resources. However, geolocating resources is not enough to support learning activities where students explore and interact with the outdoors physical environment practicing in situ related knowledge and skills. This paper studies the factors that have to be considered when designing, virtually or in situ, this type of mobile learning scenarios. Two experiments illustrate and analyse these factors. The results lead to a set of implications - in design, enactment and monitoring - for the development of mobile learning systems.

Keywords
Mobile learning, context-aware, outdoors learning, geolocation.

1. Introduction

Over the past decade, researchers have studied the benefits of using smartphones as appropriate tools for supporting Contextual Life-long Learning (CoLL) (Sharples, Corlett, & Westmancott, 2002). Sharples et al. define CoLL as the type of learning that happens when a person reflects on a current situation (occurred in a specific time/place) and has to resolve a problem, share ideas or to gain an understanding considering the context. In this line, Jeng, Wu, Huang, Tan, & Yang, (2010) provide a categorization of contextual m-learning activities, distinguishing between: (1) “Everywhere/everytime activities” benefiting from the ubiquitous mobility that smartphones have; and (2) “Situated” activities which have to take place in a specific physical space enabling the learners to reflect and learn about the environment by interacting appropriately with it.

In particular, focusing our attention on the categorization of situated m-learning, Hwang, Tsai, & Yang, (2008) define the characteristics of this type of educational settings as: “context-aware u-m-learning environment”, (i) it can be sensed, used to conduct an activity, and to offer adaptive supports; (ii) provides supports in the right way, right place, and at the right time; (iii) enables seamless learning within a predefined area; and (iv) is able to adapt the subject content to meet the functions of various mobile devices.
As we can observe in context-aware m-learning, the learning actions have to occur in specific real spaces which are connected to digital data. A huge number of studies have been conducted in order to study the benefits of this type of activities. In fact, researchers mainly distinguish between indoors and outdoors m-learning activities (Rogers et al., 2005, Rogers & Price, 2008). Particularly, Rogers et al. refer to outdoor settings (e.g., parks, city centers, woodlands) and to indoor settings (e.g., museums, learning centers, labs, home). Basically, this distinction is based on: the architectural constraints of the space, but also on the type of technology that has to be employed to conduct the activity. Specifically, an indoor space is defined as closed physical space determined by the constraints of architectural components, such as walls, doors, corridors, floors, and stairs (Ki-Joune, 2008). The inability of GPS to work effectively indoors makes impossible to use this technology as a location-based system (LBS) to mediate m-learning activities in this type of settings (Yau, Joy, & Dickert, 2010). For this reason, researchers employ other location-based technologies such as RFID, QR-Codes or Bluetooth to conduct indoors m-learning activities (Ghiani, Paterno, Santoro, & Spano, 2009; Lung-Hsiang, 2011; Pérez-Sanagustín et al., 2011).

On the contrary, an outdoor space is typically an environment which is not limited by architectural boundaries, and where it is possible to receive GPS signal.

In this paper, we study the similarities and differences among diverse possible m-learning in situ activities which are mediated with GPS data and conducted in outdoors settings. As Rogers & Rice (2008), we also use the term “in situ” to describe context-aware/situated learning activities. We claim that the characteristics of outdoors spaces determine the design method of potentially successful learning in situ, and that the design process has an effect on the enactment and monitoring phases.

Within this context, we propose a categorization of outdoors m-learning in situ activities which is based on the design process: (1) Designing virtually and (2) Design in situ. In order to illustrate both types of activities, two real scenarios are presented and analyzed: (1) An experience was carried out with a group of students and teachers of a High School in Catalonia. An exploratory activity with 70 geolocated questions were conducted in the city of Girona with the aim of putting in practice skills and knowledge learnt in the Art History course. The students had to answer the questions that appear in their mobile devices when they were in specific positions. The teacher monitored the progress of the activity in real time. (2) The second scenario was conducted in the Botanic Garden of Barcelona. The teacher of the botany course, in the university degree of Biomedicine, designed a route of 26 geolocated questions distributed over different parts of the garden. In this case, due to the characteristics of the space and the
objects to explore, the design of the routes was first pre-defined by the teacher *in situ*. Students explore the botany garden, finding the corresponding plants, interacting with them in order to answer the questions. The results obtained from these experiments have been evaluated and analysed to propose a set of implications which have to be considered during the design, enactment and monitoring phases of m-learning *in situ*. These implications can be used by developers to design appropriate m-learning *in situ* systems, and by practitioners as good practices to conduct these activities.

In both experiments, an extension of the QuesTInSitu system was used as the authoring tool and mobile app to design, enact and monitor the m-learning activity *in situ*. QuesTInSitu is a software implementation based on the IMS Question and Test Interoperability (IMS, 2006) and Google Maps to support formative assessment *in situ* (Santos, Perez-Sanagustín, Hernández-Leo, & Blat, 2011). Assessment *in situ* refers to a type of activity where the questions of a test have to be answered in front of a related real location taking into account the contextual information of the environment. During the edition of the route-test each question is associated with a real geographical coordinate. After conducting some experiments, the results presented in (Santos et al, 2011) have been used to improve QuesTInSitu. This paper presents the LBS functionality implemented in QuesTInSitu used to know the students’ positions, manage the geolocated questions and monitoring the progress of the activity in real time.

In addition, this paper studies how the design process of assigning the educational resources (e.g. questions) to geolocated data differs depending on the characteristics of the educational setting (area and objects) which have to be explored by the students.

The rest of the paper is organized as follows. In Section 2, we present a brief review and discussion of the state of the art in m-learning outdoors that motivates the aims of this research. Section 3 introduces the QuesTInSitu system, and especially the mobile app and monitoring functionality. The evaluated scenarios are presented in Section 4. This section also explains and discusses the research questions and the results of the experiments. Section 5 includes the discussion and the proposed implications for m-learning *in situ* using GPS data in outdoors settings. Finally, Section 6 includes the conclusions and the future work derived from the contributions of this paper.

## 2. Learning *in situ* outdoors

Teaching outdoors has been studied in education even before the emergence of mobile technologies (Hammerman & Hammerman, 1973). In fact, one of the concerns is how to include learning and
assessment procedures outdoors in the educational curriculum. Typically, these activities have been categorized as informal learning activities, because their lack of instructionalism and alignment with the curriculum. As Hofstein and Rosenfeld (1996) indicated: “the main objective should be to create learning environments which allow students to interact physically and intellectually with instructional materials through ‘hands-on’ experimentation and ‘minds-on’ reflection”. These authors studied how to bring the gap between formal and informal science learning (which we propose that can be extensive to other learning areas). They indicated that informal learning activities are done outdoors (out of the school), normally as optional activities, such as a supplement to formal learning. In fact, the authors proposed that informal learning experiences can occur in formal learning environments (e.g., schools) as well as informal learning environments (e.g., museums, zoos).

According to that, multiple authors (Chan, Roschelle, Hsi, Kinshuk, & Sharples, and 16 others, 2006) propose that Technology Enhanced Learning (TEL) and especially the use of handheld/mobile devices offer the opportunity to explore and investigate other learning settings (e.g. outdoors spaces) in order to extend formal learning, usually limited to the classroom, into informal learning time. This means that this technology can be employed to blurry the boundaries between formal and informal learning. The inclusion of this technology, with an appropriate instructionalism, can connect the learning spaces (classroom and outdoors) and the learning activities which can be conducted in each space.

In order to conduct in situ learning activities outdoors it is necessary to understand how the students can interact with the space and objects of the selected environment. Hwang et al. (2008) propose twelve models (centered on students tasks) for conducting context-aware ubiquitous learning activities. As a summary, the main characteristics of these models are that these environments have to provide support for: online guidance, online test based on real-world object observations, real observation/identification; collecting data via observation and sensors, problem-solving via experiments, searching digital data and supporting cooperation between students. Hazas, Scott, & Krumm (2004) indentified that the current and most used location-aware technologies are the GPS, the Bluetooth and the RFID. In addition we propose to add to the list the use of QR-Codes (Rouillard, 2008). This group of technologies makes possible to implement m-learning in situ activities.

As we have indicated in the introduction, the focus of this paper is to study m-learning in situ activities using GPS as LBS. However, we review briefly the use of RFID, Bluetooth and QR technologies. RFID/QR/Bluetooth are typically used when the authors of the activity have a control over the area that is
going to be explored by the students. RFID and QRs are tag-based technologies, this mean that a tag has to be positioned in a specific place by the author. These technologies require a user to scan the corresponding tags (Verbert et al., 2012). In the case of Bluetooth, it is necessary to have a device in a specific position constantly sending the corresponding signals to other devices. One conclusion is that the use of these technologies affects directly to the design of the activity, the design has to be in situ. It is difficult or impossible to use these technologies when our aim is to conduct an activity in a big outdoor space (e.g. different districts of a city) or in a private outdoor space (e.g. a natural park, a zoo) where authors do not have the possibility of positioning tags or fixing devices. As a consequence this means that part of the design process have to be in situ, where teachers have to put tags/devices in the corresponding places.

On the contrary, the use of GPS enables authors to design activities without necessarily having to be physically in the real space. However, after studying different real cases, we have observed that in some occasions the use of this technology is limited by the characteristics of the space, and that the design has to be done in situ. In this paper, we analyse the design, enactment and monitoring of m-learning in situ outdoors activities mediated with GPS, and the derived implications.

The support of GPS by smartphones transforms these devices into contextual-aware sensors (Johnson, Smith, Willis, Levine, & Haywood, 2011). A GPS receiver (included in the smartphone) estimates the geographical position by measuring satellite signals’ time difference of arrival. Although GPS offers near-worldwide coverage, its performance degrades indoors and in high-rise urban areas, and receivers have a relatively long start-up time and high cost, for this reason GPS are basically used in outdoors settings (Hazas et al., 2004). According to this information and studying various m-learning systems, which use GPS to share position, we propose that m-learning in situ activities outdoors can be categorized depending on whether the author needs to design the activity in situ or not: (1) Designing virtually, or (2) Design in situ.

- Designing virtually: this design happens when an author can design the activity without interacting with the real physical area. A web map service which provides information of areas and coordinates is enough to design the activity. In this case, the geolocated educational resources are associated to easily visible physical objects (e.g. buildings, monuments, urban furniture) or specific sub-areas of the space (e.g., a square, a bus station, the surroundings of a cathedral). The following systems are examples of applications that support the type of activities that can be designed in these settings: (a)
Savannah (Facer et al., 2004) is a mobile learning game based on the use of GPS and PDAs. The aim of the game is to explore an outdoor space providing a simulation of a virtual Savannah (based on long grass, short grass, gully, kopje, spring and trees areas). The main challenge for the children is to understand and survive in this territory playing the role of a lion. The system accepts the students’ inputs and transmits the location information and events. In order to design the game it is necessary to determine the locations of the outdoor game area. Savannah provides a map which simulates different areas of a real “savannah”, the author can associate an area of the map to a specific real area associating GPS coordinates. When students enter to a specific area (e.g. associated for example with “short grass”) some events occur. The second example, (b) Treasure-HIT (Kohen-Vacs, Ronen, & Cohen, 2012) allows teachers to define a set of locations, using Google Maps, and associate clues or activities. Students can play the routes using their smartphones. The system is aimed to support the subject “My Village” as part of the national curriculum for elementary schools. The game offers the possibility of using a Google Street View for further position refinement. Teachers can also control the minimal required distance from the site (authors named that as Tolerance), within the limitations of the GPS technology. The Treasure-HIT player application serves for interaction during the game. It provides the clues for each station, verifies player’s location, displays feedbacks and presents additional activities according to the player’s performance. The activity definition includes the location setting for each station, the sequencing of the stations, the clues and activities related to each station and the feedback provided to students during the game.

- Design in situ: this type of design has to be applied when authors cannot be sure of the characteristics of the area using a digital map. In this case, the author has to design the activity interacting with the real physical area. S/he has to associate physical positions to coordinates in situ. Normally, it occurs in changeable environments such as a natural park or a garden (where plants are modified depending on the weather), or an outdoor exhibit (with sculptures that can be moved). The following systems are examples of applications that supports the type of activities that can be designed in these settings: (a) The Mobile Plant Learning System (MPLS) (Huang, Lin, & Cheng, 2009) is a system implemented for PDAs which makes use of GPS data to provide course material associated to positions of a botanic garden. Students have the possibility of associating information in situ (e.g. audio) to specific areas of the garden, and also the system can detect the learner’s location and identify which plants surround them. The system shows a map to help the students to identify the
plants, and perform specific tasks (e.g. measuring the plant, making pictures, reading information…).

The MPLS have a database which contains the relation between area of plants and coordinates. The system allows users to conveniently add or modify data about a plant, augmenting the database with new relations of plants-coordinates. With this system it is necessary to go to the real place (in situ) to know how to design the association between plants and coordinates. The second example of design in situ is illustrated with (b) Explore! (Ardito et al., 2008). This is an m-learning system which is based on an excursion-game technique which goal is to help middle school students acquire historic knowledge while playing in an archaeological park. The game was especially designed for a visit to the archaeological park of Egnathia, an ancient Roman city in the Apulia region in Southern Italy. The aim is to help students learn history while playing a game. Students have the opportunity to explore 3D reconstructions of historical buildings, objects, and places. The system provides contextual sounds that recreate the historical atmosphere. The intensity of the sounds changes dynamically according to the learners’ physical position, acquired from GPS. In this case, due to the details of the different exhibits of the archaeological park, it is necessary to design part of the activity in situ to ensure the correct position of sounds and tasks.

In order to understand better the implications of designing virtually or in situ, we conducted two experiments using our own m-learning in situ system named: QuesTInSitu. One experiment (Exploring in situ the History and Art of Girona’s outdoors) was conducted following a virtually design of the activity, the other one (Assessment in situ at the botanic garden of Barcelona) was designed in situ. In both experiments we use a participatory design approach with teachers in order to understand the information that they need to design their corresponding activities. In addition, we have explored how students interact with the system as a location-aware guide during the real activity in situ. One of the aims is to understand which is the information needed by students to facilitate the exploration and location of geolocated resources. Finally, after studying similar systems, we have encountered that these are focused on supporting the design phase (for teachers) and the enactment (for students), however during the enactment it is important to facilitate the monitoring of the activity to the teachers. For this reason, we also explore and propose implications to support teachers when students are playing the activity. The following section gives more details about QuesTInSitu, the system used to design, enact and monitor the activities of the experiments.
3. QuesTInSitu: an app for formative assessment in situ outdoors

QuesTInSitu, has been especially designed to support formative assessment in situ using smartphones and LBS. In an assessment in situ activity students put into practice transversal skills such as exploration, spatial and observation besides of the specific skills related with the content of the test. The aim is to provide support for creating and answering routes of geolocated questions. In a previous publication (Santos et al., 2011) the first version of QuesTInSitu was presented. In this paper we present the new functionalities and improvements included in the system considering the results of previous experiments. The first version of QuesTInSitu did not include its own LBS, MScape (Stenton et al., 2007) was used to detect the students’ position and trigger the questions in the specific locations. After doing experiments using the past version of QuesTInSitu, we realised that it was a better option to detect the students’ position using QuesTInSitu instead of using MScape. The main reason is because using QuesTInSitu as a LBS the students’ position can be saved in our own database. The new version of the mobile app has access to the students’ positions. This information is used for triggering questions automatically, and also to monitor the students’ position in real time.

Figure 1 shows how the QuesTInSitu control module is connected with other components. The NewAPIS engine (Blat, Navarrete, Mognieh, & Batlle, 2007) manages the QTI tests and questions. This engine is in charge of rendering the questions, checking the responses and providing the feedback and scores. Google Maps is the web map service selected to provide the geographical information. As it has been indicated before, QuesTInSitu acts as LBS, connecting the information provided by the mobile app (which receives the GPS position of the smartphone) and comparing this position with the coordinates of each question saved in the database.

*** Insert here Figure 1 ***

Teachers can position questions over a map, and they can design virtually the contextual activities (see the Web Graphical User Interface in Figure 1). The map can be used to find the corresponding positions, and making a click the teacher can associate a question with a coordinate. Currently, QuesTInSitu does not have a mobile app for designing in situ the questions. However, we have evaluated with teachers which functionalities QuesTInSitu should offer to provide an appropriate support for this type of design. This aspect is evaluated in the experiment: Assessment in situ at the botanic garden of Barcelona.

The QuesTInSitu mobile (QTISM) app enables students to access (using their username and password) to the different routes of geolocated questions published in the system (see Figure 2.a). Once the students
select a route, they can view a map that contains the positions of all the questions that they have to
discover (non-answered questions are represented with a star icon, questions answered correctly with a
green flag icon, and incorrect question with a red flag icon) and they can see their own position
(represented with a “people” icon), an example is showed in Figure 2.b. When the student is in an area
closed of the coordinate, the question appears on the screen of the smartphone (see Figure 2.c). Students
need to be located in situ in order to understand and answer the question, and they have to interact with
the real environment (observing, touching, talking with people, etc.).

*** Insert here Figure 2. QTISM (a) select a route (b) play a route (c) answer a question ***

QuesTInSitu provides support to teachers during the enactment. Teachers can monitor in real time the
progress of their students. Teachers can see over a map the position of their students during the
experience. As Figure 3 shows, a map contains the positions of the different students who are playing the
activity (these are represented with the number of their group) and the geolocated questions are
represented with yellow markers. In order to know the punctuation of the students in the different
questions, teachers can interact with the yellow markers and a pop-up shows the relation of
scores/students for the selected question. The information is updated in real time. Teachers can
continuously analyze this information and react contacting the groups, if needed. Some examples in
which teachers may react are, for instance, when detecting that one of the groups is out of the perimeter to
explore, or when students are having more problems than expected with the questions. Though initially
considered as a potentially interesting facility, QuesTInSitu does not include any communication
functionality between teachers and students.

*** Insert here Figure 3. QuesTInSitu monitoring***

The new version of QuesTInSitu has been used by the participants of the experiments explained in this
paper. The results obtained from the evaluation help us to understand which functionalities are
appropriate for doing this type of activities, and which ones have to be improved.

4. Two experiments of m-learning in situ outdoors with geolocated questions

One of the aims of this evaluation is to validate whether the following statement is true or false: “The
characteristics of outdoors settings condition the design method and the enactment and monitoring
phases of successful learning in situ”. In addition, this section presents two scenarios evidencing the
design process followed to implement assessment in situ outdoors, and how this design has an effect on the enactment and monitoring of the activity.

A real educational experience for learning Art History concepts about the city of Girona has been designed, evaluated and put into practice with 1 teacher and 62 students (boys and girls with an average of 17 years old). In the experience the QuesTInSitu system was used one the one hand, by the teacher to design virtually the route of questions and monitor the activity in real time. On the other hand, students used the mobile app to discover and answer the questions in situ. The technological solution facilitates the design of the questions without having to be physically in the real space. Besides the automatic assessment and monitoring of the students’ responses and the provision of feedback and score in real time. The evaluation of the experience is performed with the aim of analysing the use of the system during the different phases: design, enactment and monitoring. Next, with the objective of understanding how QuesTInSitu has to be improved to allow teachers to design in situ, another experiment is included in the paper. The second experiment is also framed in a real educational context. Two teachers of the Botany course of the Biomedicine university degree designed a route of geolocated questions to put into practice the knowledge and skills taught at classroom. Considering the characteristics of the activity, the design was carried out in situ. The main reason was because the teachers had to be sure that the corresponding plants were in appropriate conditions before the realization of the activity. The design in situ was evaluated in order to understand the needs of the teachers. The day of the activity, 50 students used in groups the QuesTInSitu mobile app to answer the questions finding, observing and interacting with the plants.

The results of the evaluation of both experiments enabled us to understand the differences between the two types of activities (design virtually and design in situ) and how the design and the outdoor space conditions the enactment and monitoring of the activity.

4.1 Research question and objectives

The main research question of the experiment was: Can the outdoors setting affect the design of the m-learning activity and its success?

In order to satisfactorily answer this question two experiments have been conducted with the following objectives:
• **Evaluating the differences of designing virtually and a design in situ.** We study the two types of design processes with the aim of understanding which are the functionalities that a m-learning *in situ* app (for outdoors with GPS) has to include in order to provide appropriate support during the design of the activity.

• During the enactment, **teachers have to monitor in real time the progress of the students.** The information provided to the teachers has to be useful for controlling the effectiveness of the activity. Teachers need to know where the students are located during the activity in order to detect that students are following the route correctly. Also they have to know whether students are answering correctly the questions in order to detect misunderstandings.

• **The way of designing and structuring the m-learning *in situ* outdoors activity has to encourage the students to explore the environment.** In an outdoor activity students need to be guided in order to discover the geolocated digital resources. Our aim is to understand the information that students consider as beneficial and the functionalities that they miss in the mobile app, but also other resources that help them during the activity.

• Moreover, **the activity has to facilitate a successful learning *in situ*.** We seek to understand to what extend the technological solution helps the students in their tasks during the activity and have a positive effect in their learning.

### 4.2 Methodology and Data Gathering Techniques

A mixed method has been applied for doing the evaluation of the experiment due the characteristics of the educational contexts, involving teachers and students in real settings (Guba, 1981). The need of involving human subjects in the experiences made it difficult to use a controlled method, which requires multiple instances of an observation in order to provide statistical validity. Because of the enormous cost of replication (in our context, the possibilities of organizing experiences with students and teachers), the controlled experiments are often limited to few replications, which seriously increases the risk related to the validity of the results (Stake, 1995). A mixed approach is a suitable method because its mixed nature provides guidelines that facilitate the understanding of the experiments. Qualitative data such as the teachers and students’ perspective can be collected using data sources such as: observations, interviews and questionnaires (with open questions). Quantitative data has been collected such as: the occurrence of actions during the activity, the data saved in QuesTInSitu and the answers to closed questions in
questionnaires. The quantitative analysis is used to detect tendencies, which are confirmed or rejected through the analysis of the qualitative data. The different data collected used for the evaluation are described in Table 1, the same type of data sources was used on both experiments. The data collected were first analyzed and next triangulated in order to obtain trustworthy results.

*** Insert here Table 1. Data collected ***

In both experiments we follow a participatory design (Schuler & Namioka, 1993) in order to understand the requirements and steps that teachers follow during the design of the activity. The participatory design consisted in collecting the information generated by the teacher, observe how they create the routes and discuss with them the advantages and limitations of the QuesTInSitu’s authoring tool.

4.3 Exploring in situ the Art History of Girona

One teachers and a group of second bachelor students of the Escola Pia Santa Ana de Mataró (http://mataro.escolapia.cat/2012/03/questinsitu-girona.html) participated in the outdoors activity in situ. The activity was an adaptation of an activity carried out in previous years where the teacher explored with their students part of the Catalan city of Girona (in previous years without using any technological solution). The aim was to use QuesTInSitu to enhance the activity with enriched assessment in situ. One of the issues was to enable the teacher to design a route of geolocated questions without having to be physically at Girona (mainly because the school was located far away from this city). 70 geolocated questions were designed as an open exploratory activity. It was not necessary to answer all the questions but the teacher decided that the group with more correct questions would be the group that fixed the highest mark. The aim of the activity in situ was to answer the questions remembering the lessons learned at classroom. But students also have the possibility of finding the answers talking with the citizens, searching on Internet or making calls. Some of the questions of the exploratory route were selected by the teacher to do an exam at classroom as a post-activity. The goal of this teacher was to compare the students’ scores obtained in situ and the exams’ scores.

The 62 students were organized in a total of 20 groups. One of the objectives was to understand how students interact with the mobile app and the advantages and limitations of using geolocation for guiding the students in an outdoor setting. In addition, we observed the teacher monitoring the progress of the students during the activity. Figure 4 shows different pictures done during the activity in situ, we can see
the graphical interface of QuesTInSitu showing the map with the route of questions and how a question looks. The picture also shows, the students interacting with the smartphone and discussing about the questions. And finally, we can see the teacher monitoring the activity using an iPad and their laptop.

*** Insert here Figure 4. Discovering Girona in situ with QuesTInSitu ***

4.3.1 Results and analysis

*Design Phase*

The design of the activity was conducted following a participatory design approach with the teacher. Before interacting with QuesTInSitu, we asked to the teacher to think about how to design the activity. The objective was to observe which information was necessary for the teacher to organize the design of the activity. The teacher handed the following documents: (D1) A list linking the areas to explore and the number of questions per area; (D2) A document containing the areas to explore and the text of the questions with the corresponding options and feedback. In addition, the teacher was worried of ensuring that the selection of incorrect options would affect to the final score according with a specific formula established in the educational curriculum of the subject. He also created (D3) a spreadsheet document for calculating the scores. Finally, the teacher delivered (D4) a document indicating the general rules and schedule of the outdoors activity. The documents are summarized in Table 1.

The information of the documents (D1) and (D2) was used to geolocate the questions using QuesTInSitu. It was easy to use the digital map for geolocating questions inside the pre-determined areas. In this case, inside each area it would be easy for the students to find the physical objects (buildings, sculptures, shops) related with the questions.

Analyzing these documents and the observations extracted during the participatory design, the results obtained in the design phase are: [GR1] teachers need to organize the activity in subareas, and inside these subareas they locate the corresponding educational resources. Another observation [GR2] from Document (D3) was that during the design process a requirement is to enable the edition of the grading mechanisms. Finally, after discussing the document (D4) with the teacher, we observed that [GR3] the time factor is very important when planning the activity. For instance, the main time-based information is: the day (or days) of the activity, the start and finish time.
Enactment Phase

The partial results (summarized in Table 2) are obtained from: 32/62 participants that answered the final questionnaire [Q-st-route] and observations taken by researchers during the activity [O-st-route].

*** Insert here Table 2. Partial student’s results during the enactment phase ***

The main results of the analysis are described in what follows:

During the activity in situ students used a smartphone with QuesTInSitu, a tourist map of the city, the document (D1) with the number of questions per subarea and other mobile phones. According with the partial results we observed that the students valued as very useful the paper map and the document (D1) with the subdivision of areas. But also, students scored positively the map and guide offered by QuesTInSitu. In fact, students indicated that: “Using smartphones for exploring the city” and “knowing your position in real time” [commented by various students in the questionnaire] was one of the three most positive aspects of the activity.

Interestingly, students valued more positively the paper map vs. the map showed on the smartphone [GPR1, GPR4]. According with the observations noted during the activity, this is due mainly because of the size of the paper map, “The students looked the document provided by the teacher (D1), marked the information in the paper map using a pen, and then discussed a strategy” [O-st-route]. However, the students pointed out as very useful the use of the smartphone as LBS in order to know their position and the automatic apparition of questions. The positive punctuation of the document (D1) shows that students appreciate to have information about the quantity of subareas that they need to explore and the quantity of educational resources in these areas. Some students commented: “We could know (with QuesTInSitu) where we were located” [student11]; “(I liked) see the points where the questions were located” [student30]. As first result of the enactment phase [GR4] we observed that combining digital maps and paper maps is beneficial for the activity, the paper map is used to have a global view of the whole area to explore, and the digital map (QuesTInSitu) is used mainly to be focused in the sub-area of questions.

The partial results [GPR2, GPR3 and GPR4] summarize the evidences showing the behaviour of students when they did the learning tasks in situ. All the groups have a similar behaviour: (1) first of all they planned the subareas to visit, (2) then they found the questions using QuesTInSitu and the maps, (3) once a question is displayed the student who carried the smartphone read aloud the question, (4) all the member tried to find the answer (observing the environment, talking with citizens, searching on Internet
or making calls) and they discussed until being agree with one of the options, (5) finally they answered the question and read aloud the feedback. Students’ comments complement these evidences: “You can know in real time if the question is correct” [student26]; “If I answered the question correctly or incorrectly, I know it at the moment” [student25]; “The students used their mobile phone for searching on google or Wikipedia, information for solving the questions” [O-st-route]. Considering this information, the result [GR5] proposes that the automatic apparition of educational resources (one question or various) in the associated place and the possibility of receiving feedback in situ help students to understand better the questions and especially motivates them to explore the area visited, learning and reflecting in situ about the details of the visited area.

Finally, the comments of the students and the observations summarized on the partial results [GPR4, GPR5 and GPR6] have been used to understand the collaborative behaviour of the students during the activity. The teacher decided to make group of students to perform the activity in situ, for this reason it was necessary to understand if all the members of the group contributed to the learning tasks. The third result [GR6] shows that students prefer to do contextual-aware m-learning activities outdoors in groups because they can collaborate and share their experience with their classmates, and they can discuss the tasks in order to find the best answer.

Monitoring Phase

Especially the observations [O-st-route, O-t-route] taken during the activity in situ were used to understand the monitoring tasks carried out by the teacher. The devices used by the teacher during the activity were: a laptop and an iPad. Principally the teacher used the iPad with 3G connection to monitor the activity in different locations of the city. While the students were exploring the city, the teacher was also walking around with the objective of coming across dispersed groups of students face to face. Besides, we also observed that he was interested in knowing the position of all his students. As a first result of this phase [GR7] we state that the position and the progress of students during the activity (incorrect/correct tasks done, problems occurred) is essential information that teachers need to know during the monitoring.

In addition, the observations done by a group of researchers during the activity showed us the second result of this phase [GR8], this is that the students and the teachers have the necessity of being communicated during the activity. QuesTInSitu does not have any communication functionality.
However, students (among them and with the teacher) used common communication apps for being communicated during the activity, they used: twitter, whatsapp and the e-mail. In particular, on the one hand, the whatsapp application was used between the students to share their personal comments. On the other hand, the teacher sent e-mails to alert about important time-related events (e.g. 1 hour of extension of the activity). Finally, the group of students and other teachers of the school, decided to use a hash-tag on Twitter to share impressions and pictures during the activity. In fact the main teacher, and other teachers that helped during the activity selected the most important tweets and created a story of the activity using the web application named Storify (see: http://storify.com/ismaelebezudo/ruta-geolocalitzada-d-historia-de-l-art-a-girona).

4.4 Assessment in situ at the botanic garden of Barcelona

Two teachers of the Botany course of the 1st year of the Biomedicine degree of the UPF’s university decided to design an activity with geolocated questions at the botanic garden of Barcelona. As in the activity done at Girona, the Botanic activity was an adaptation of an activity carried out in previous years where the teacher explored with their students part of the garden without technological support. In order to design the activity the teachers indicated that it would be necessary to go physically to the garden to know the current status of the plants and then, in situ, think about the corresponding questions. This scenario provided us an opportunity to conduct a participatory design process focused on identifying the main requirements for authoring support when designing mobile learning activities in situ.

The goal of this activity was to promote the exploration of the garden, and make students interact with the plants and reflect about the questions in situ. The 50 students were organized in 20 groups.

In this case the questions did not appear exactly in front of the corresponding places (due to the inaccuracy limitations of GPS), for this reason one of the objectives was to understand the behaviour of the students finding the plants associated to the questions. We also observed the behaviour of the teacher in this setting. Figure 5 shows the students interacting with their smartphones and exploring the botanical garden in order to discover the questions.

*** Insert here Figure 5. QuesTInSitu and the Botanic activity in situ***

4.4.1 Results and analysis

*Design Phase*
The design of this activity was different than the design of the Girona in situ, due to the characteristics of this changeable environment. In this case, it was impossible to design the activity using a virtual map because teachers required knowing which plants were in appropriate conditions to ask questions about them. For this reason, the teachers and researchers went to the garden to decide where the questions had to be located. In line with our objective of understanding which functionalities teachers need during the edition in situ, we compared three different applications that allow users to save their position and associate notes. The applications were: (1) a Geocaching app with a Garmin GPS device (available: http://www8.garmin.com/outdoor/geocaching/): this application enables the association of notes to coordinates, once the route is created it can be exported to the computer; (2) GetMyPos IOS App (available: https://itunes.apple.com/us/app/getmypos/id502142744?mt=8): an app which allows the author to send e-mails with annotations and the information about the coordinates of the specific position. And finally, the third app selected was (3) WayPoint Android App (available: https://play.google.com/store/apps/details?id=com.thedroiddev.waypoint&hl=en): allows authors to save and manage “waypoints”, it means coordinates and notations. Waypoints can be plotted on a map to access information about the waypoint or viewed in Google Maps to access directions, streetviews, or topographical map data if available. The goal of comparing these different apps and devices was to understand which type of support teachers need during a design in situ.

The two teachers used the applications in situ and researchers noted observations, after the design in situ teachers answered a questionnaire [Q-teacher].

After comparing the three applications, the two teachers agreed on choosing the WayPoint app as the best tool, because it was the only one that enables the addition of points and their visualization in the same application where the information is edited. They indicated that the Garmin device was ease of use, but the problem was to have to download all the data to the computer to have the possibility of visualizing it. Finally, the GetMyPos app was valued with the lowest score because they commented that managing all the received emails (with the coordinated and description) separately would be problematic.

Considering this information, as a result [BR1] we claim that the design in situ has to enable teachers to do a sketch of the final route. This sketch is formed by the corresponding coordinates, where questions will be positioned, and short notes indicating the topic of the question. The next steps of the design have to be finished with a web authoring tool. For example, one of the teachers indicated that they imagine the design in situ such as: “First, I could make a series of points on an area or
route (in situ), and then (after the design in situ) edit the questions or activities related to each location” [teacher1]. Figure 6 shows the resultant sketch after designing in situ the activity. Teachers observed the environment, and decided in situ the plants and areas for the activity. In each position they put a name of the plant. They used these data to finish the final text of the questions and the options virtually using QuesTInSitu.

*** Insert here Figure 6. Sketch of the geolocated data during the design in situ***

During the design in situ teachers wondered to divide the tasks and edit different positions of the same activity at the same time. In addition, they were worried of having the opportunity of deleting questions, and also they indicated: “(I am worried) of distributing the questions to avoid overlap” [teacher2]. The behaviour is summarized as the result: [BR2] the design in situ has to allow authors to edit collaboratively, it has to offer the possibility of re-edition and the data have to be visualized over a map.

It is necessary to mention that after the activity, teachers also prepared a document, such as the (D2) mentioned in the previous scenario, relating questions with specific sub-areas. This also supports the result [GR2] of Girona in situ activity.

**Enactment Phase**

The partial results (summarized in Table 3) are obtained from: 35/50 participants that answered the final questionnaire [Q-st-route] and also from observations taken by two researchers during the activity [O-st-route].

*** Insert here Table 3. Partial student’s results during the enactment phase***

The main results of the analysis are described in what follows:

The students explored the botanic garden during 1 hour and 30 minutes, at the beginning of the activity the teachers explained the activity. Each group was formed by 3 or 4 students, and they carried out a smartphone with QuesTInSitu, a paper map guide of the garden and some of the students also have notes taken during the course, a botanic book with descriptions of plants and other mobile devices.

One of the goals of the experiment was to understand the behaviour of the students when a question is displayed and then they had to find the corresponding plant in the nearest area. [BPR1 and part of BPR4] show the students behaviour indicating that both maps, QuesTInSitu’s map and the map-guide, were useful for exploring the garden. These partial results reinforce the result obtained in the Girona in situ
experiment, the result [GR4]. **Confirming that the paper maps are used to view the global area to explore (the garden) and the map showed in the screen of the smartphone is used mainly to be focused on the specific area where students are situated.**

The partial results [BPR3, BPR5] showed that once a question is displayed students spent some time understanding the description of the plant and exploring the environment before finding the correct one. This was due to the inaccuracy of the GPS, questions appeared inside of a diameter of 20 meters nearest of the specific plant but not just in front of the plant. **As a result we state [BR3] that in an outdoors activity like a garden, where students have to find specific small objects (such as a plant), students make an extra effort exploring the environment in order to find the object and do the task.**

The following students’ comments evidenced their behaviour during the activity: “*(We) read the description of the plant, we found it inside a radius of 12 meters and then we answered the question*” [student22]; “*The questions are displayed far from the associated plant*” [student31].

Relative to this result another interesting partial result [BPR3] shows that one of the most positive aspects of the activity, valued by the students, was the description added by the teacher before the text of the question. When a question is displayed, students read the description and all the members of the group discussed and explored the area until they found the question (taking the description as a reference to find the plant). This behaviour evidences the second result which indicates that [BR4] descriptions and hints are useful to help students in their explorative tasks. This result is illustrated by the following student’s comment: “*We searched the species according with the descriptions of the question, then we observed it and drew conclusions*” [student35].

The partial results [BPR2, BPR3 and BPR4] also can be used to reinforce the statements of the results [GR5 and GR6] previously proposed in the analysis of Girona in situ. These results evidence that students perceived the in situ m-learning activities as useful for putting in practice their knowledge and skills. Especially useful for being more familiar and doing a deeper exploration of the area visited. And, in addition, they preferred to do the activity collaboratively in groups because then they can share their knowledge and discuss with their class-mates in order to find the correct result.

**Monitoring Phase**

In this case, the teachers were not worried of using a device to know during the activity the positions of their students [O-t-route]. The reason was because the garden is not a big space, and it is easy to find the
students during the explorative activity. However, during the exploration some students did not find easily some of the plants associated to the questions. For this reason the teacher wondered about having the possibility of re-editing some of the questions during the enactment of the activity. As a first result we propose [BR5] the monitoring phase have to provide information to help teachers to know whether some questions have to be banned or re-edited during the enactment of the activity.

In addition, teachers wanted to use the monitoring data in post-activities at classroom. One of the teachers was worried about whether: “there are questions, doubts or confusions without being solved” [teacher1-comments]. As a result we state [BR6] teachers are interested on checking the information related with the students’ progress (correct/incorrect questions, time to answer questions, students’ routes) to extract conclusions from the activity.

5. Implications for contextual-aware m-learning outdoors activities mediated with GPS

The list of implications presented in this section aims to offer practitioners and developers of mobile learning solutions a better understanding of teachers’ and students’ needs along design, enactment and monitoring of learning activities in situ outdoors. Each implication is associated to one or more of the results obtained from the evaluation of the experiments. This association is indicated with a code referring to each result.

5.1 Edition
- Provide facilities to enable two main scenarios for design: virtual design processes where the editions are carried out directly over a digital map [GR1] or in situ design tasks when the physical elements of interest are (artificially or naturally) changing and it is necessary to assign short-notes to coordinates visiting the real place [BR1].
- Enable the editing of sub-areas over the map, and facilitate changes and additions to the design also (in real time) during the enactment [GR1, BR2].
- Allow authoring of grading formulas [GR2].
- Add timing parameters to provide alerts, such as: beginning of the activity, time to do specific tasks, end of the activity [GR3].
- Associate one or various learning tasks (e.g. add a group of questions) to the same point (coordinate). It is recommended to let certain distance (around 30 meters) between the different geolocated points. The reason behind is that if various educational resources appear almost in the same area, the
perception of their location is unclear and may decrease the feeling of contextual learning [GR5, BR3].

- Favour the creation of learning tasks (e.g. questions) that can only be completed being physically in situ. The effect of students’ learning enhancement about the situs is especially achieved by fostering exploration. Questions that foster exploration and interaction with the environment are around aspects that can be observed or touched or smelled, etc. [GR5, BR3].

- Add hints or descriptions about the associated specific physical objects, monuments, buildings, etc., to intensively promote the exploration of the outdoors area [BR4].

5.2. Enactment

- Combine the use of smartphones with Location-based Systems and paper maps. The combination of both types of maps is beneficial for the exploratory activity [GR4].

- Include collaboration elements. Students enjoy participating in groups doing m-learning in situ outdoors activities. Teachers can assign different roles that students can play (be the responsible of the smartphone, the person who carries the map, who makes pictures, the student that search on internet…) [GR6].

- Enable students to use external apps, already familiar to them, for communication purposes (between students, or with the teacher), thereby the m-learning app has to be focused on providing support for the contextual learning activity [GR8].

5.3 Monitoring

- Offer real-time activity progress analytics. The data collected can be showed over a map during the enactment, to facilitate teachers’ awareness of the progress of the explorative activity. After the activity, these data can be also used to visualize students’ explorative traces [GR7, BR5].

- Provide statistics reports about the assessment progress (especially important after doing the activity in situ) [BR6].

6. Conclusions

This paper discusses how the characteristics of outdoors settings condition the design, enactment and monitoring of learning in situ activities mediated with GPS. As the literature review evidences, the use of
smartphones is changing the way of learning and teaching outdoors. Different location-based technologies can be used to augment the physical space with digital data, but especially the GPS system is used to geolocate educational resources in outdoors environments. One of the main reasons to use the GPS is that authors can associate digital information to coordinates, and then these data can be accessed in situ with a smartphone sharing your position. We identify that there are two main types of design processes that can be followed when creating an m-learning in situ outdoors activity. On the one hand, a design virtually and, on the other hand, a design in situ. Designing virtually occurs when authors can use a digital map to geolocate the educational resources. Teachers do not need to be in the real physical space, and students can explore and do the geolocated tasks without having to provide an extra guide. On the other hand, in the case of design in situ, teachers need to be physically in the outdoors environment to make a first design of the activity. This is due the changeable characteristics of the setting. During the enactment we have observed that students used paper maps and the map visualized in the m-learning system to find correctly the places. An interesting future work would be to study the usefulness of using tablets for doing this type of activities (avoiding the use of paper maps). Another important observation is that descriptions or hints within the geolocated questions/tasks are especially useful for the students when they have to find specific physical objects that should be explored. The results of the experiments evaluated show that m-learning in situ outdoors is perceived as beneficial when activities are realised in groups of students. These activities especially promote the exploration of outdoors improving the knowledge about the visited area. When the area to explore is big, teachers need to monitor the activity in real time. Monitoring the actions done by the students is essential after the activity. Using QuesTInSitu teachers can monitor the students’ position and scores over a map, but as a future work we plan to explore deeply different ways of information visualization to support teachers during the monitoring.

The results of presented in this paper have been used to propose a set of implications as best practices for practitioners and developers when implementing m-learning in situ outdoors.

Acknowledgment

This work has been partially sponsored by the Spanish Ministry of Science and Innovation EEE Project TIN2011-28308-C03-03. The authors would also like to thank the rest of the members of the GTI-Learning research group for their support. And last but not least, the students and teachers of the Escola Pia Santa Anna - Mataró.
References


Figures

Figure 1. QuesTInSitu architecture (extension of Santos et al., 2011)

Figure 2. QTISM (a) select a route (b) play a route (c) answer a question
Figure 3. QuesTInSitu monitoring

Figure 4. Exploring *in situ* the Art History of Girona
Figure 5. QuesTInSitu and the Botanic activity *in situ*

Figure 6. Sketch of the geolocated data during the design *in situ*
Tables

Table 1. Data collected

<table>
<thead>
<tr>
<th>Data source</th>
<th>Type of data</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaires</td>
<td>Quantitative and qualitative answers collected from students and teachers.</td>
<td>[Q-st-route] [O-st-route]</td>
</tr>
<tr>
<td>Teacher interviews</td>
<td>Notes taken in discussions and meetings with the teachers during design,</td>
<td>[T-comments]</td>
</tr>
<tr>
<td></td>
<td>enactment and monitoring.</td>
<td></td>
</tr>
<tr>
<td>Observations-route</td>
<td>Observers’ notes about teachers’ and students’ behaviours.</td>
<td>[O-t-route]</td>
</tr>
<tr>
<td>Document 1</td>
<td>List of areas to explore and the number of questions per area.</td>
<td>D1</td>
</tr>
<tr>
<td>Document 2</td>
<td>List of areas to explore and the text of the questions.</td>
<td>D2</td>
</tr>
<tr>
<td>Document 3</td>
<td>Spreadsheet document for calculating the scores</td>
<td>D3</td>
</tr>
<tr>
<td>Document 4</td>
<td>General rules and schedule of the activity.</td>
<td>D4</td>
</tr>
</tbody>
</table>

Table 2. Girona Partial Results (GPR) during the enactment phase

<table>
<thead>
<tr>
<th>Partial Results</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students voted with an average score of:</td>
<td>GPR1</td>
</tr>
<tr>
<td>- 3,16/5 the usefulness of the QTIS map for doing the activity.</td>
<td></td>
</tr>
<tr>
<td>- 3,9/5 the usefulness of a document relating questions and subareas for doing the activity.</td>
<td></td>
</tr>
<tr>
<td>- 4,67/5 the usefulness of a paper map.</td>
<td></td>
</tr>
<tr>
<td>(0 = very useless 5 = very useful)</td>
<td></td>
</tr>
<tr>
<td>9/32 students would rather answer a unique question in a specific location.</td>
<td>GPR2</td>
</tr>
<tr>
<td>13/32 students would rather answer various questions in a specific location.</td>
<td></td>
</tr>
<tr>
<td>10/32 students don’t have a special preference regarding answering one or various questions in the same location.</td>
<td></td>
</tr>
<tr>
<td>Students voted with an average of:</td>
<td>GPR3</td>
</tr>
<tr>
<td>- 3,5/5 the usefulness of the activity for understanding and learning History and Art concepts.</td>
<td></td>
</tr>
<tr>
<td>- 4,47/5 the usefulness of the activity for being familiar with the area visited of the city of Girona.</td>
<td></td>
</tr>
<tr>
<td>- 4,25/5 the level of enjoyment.</td>
<td></td>
</tr>
<tr>
<td>(0 = very useless 5 = very useful)</td>
<td></td>
</tr>
<tr>
<td>The most outstanding 3 positive aspects of the activity (indicated freely by the students) were:</td>
<td>GPR4</td>
</tr>
<tr>
<td>- Using smartphones for exploring the city, knowing your position in real time.</td>
<td></td>
</tr>
<tr>
<td>- Knowing the response, feedback and score in real time and in front of the corresponding position.</td>
<td></td>
</tr>
<tr>
<td>- Doing the activity in groups.</td>
<td></td>
</tr>
<tr>
<td>All the groups of students did not have problems assigning themselves the tasks to do during the activity (carrying out the smartphone, searching information, using the paper map…).</td>
<td>GPR5</td>
</tr>
<tr>
<td>When a question is displayed all the members of each group acted in the same way: all of them met around the smartphone, the leader read the question aloud, they discussed the answers observing the environment or searching information in Internet, answered the question and finally the leader communicated the corresponding feedback.</td>
<td>GPR6</td>
</tr>
</tbody>
</table>
Table 3. Botanic Partial Results (BPR) during the enactment phase

<table>
<thead>
<tr>
<th>Partial Results</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students voted with an average score of:</td>
<td>[BPR1]</td>
</tr>
<tr>
<td>- 3.28/5 the usefulness of the QTIS map for doing the activity.</td>
<td></td>
</tr>
<tr>
<td>- 3.14/5 the usefulness of a paper map.</td>
<td></td>
</tr>
<tr>
<td>(0 = very useless 5 = very useful)</td>
<td></td>
</tr>
<tr>
<td>Students voted with an average of:</td>
<td>[BPR2]</td>
</tr>
<tr>
<td>- 3.2/5 the usefulness of the activity for understanding and learning Botanical concepts.</td>
<td></td>
</tr>
<tr>
<td>- 3.84/5 the usefulness of the activity for being familiar with the area visited of the garden.</td>
<td></td>
</tr>
<tr>
<td>- 3.56/5 the level of enjoyment.</td>
<td></td>
</tr>
<tr>
<td>(0 = very useless 5 = very useful)</td>
<td></td>
</tr>
<tr>
<td>All the group of students had the same behaviour when a question appears:</td>
<td>[BPR3]</td>
</tr>
<tr>
<td>- (1) first they read the questions aloud, then (2) they explored the nearest area finding the plant, according with the description, (3) they interacted with the plant, discussing and sharing information (4) they reached a consensus on the final answer and (5) checked the feedback and used it to make the final reflection.</td>
<td></td>
</tr>
<tr>
<td>The most outstanding 4 positive aspects of the activity (indicated freely by the students) were:</td>
<td>[BPR4]</td>
</tr>
<tr>
<td>- The map indicating where you are inside the Garden</td>
<td></td>
</tr>
<tr>
<td>- The automatic apparition of questions and answers</td>
<td></td>
</tr>
<tr>
<td>- The brief explanation (description of the plants) before the Questions facilitates the searching for plants</td>
<td></td>
</tr>
<tr>
<td>- Doing the activity in groups</td>
<td></td>
</tr>
<tr>
<td>Some students had difficulties for finding some of the plants since the questions did not appear exactly in front of them (limitations in GPS accuracy).</td>
<td>[BPR5]</td>
</tr>
</tbody>
</table>