Space-aware Design Factors for Located Learning Activities Supported with Smart Phones

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Mobile technologies are currently being applied to facilitate the development of learning activities in diverse spaces beyond the classroom. Indoors and outdoors spaces are augmented with located digital Educational Resources (ER) through specific technologies that provide a sensory input to smart phones that can indicate position and, thus, enable located learning activities. Especially, the potential that smart phones have, make these devices adequate to facilitate the access to located ERs. This paper proposes four space-aware design factors (the space, the connectivity, the position-based technologies and the guidance) that have to be considered for designing located learning activities supported with smart phones. The application of the factors is explained through four illustrative located learning scenarios. The paper discusses how the combination of these factors affects the design of the activity, accessing to the ERs and monitoring the students' progress.

Space-aware design factors, located learning activities, smart phones

I. INTRODUCTION

During the last decade the use of mobile devices with educational purposes is increasing. Current smart phones are equipped with location-based systems, QR-Code/RFID/NFC readers, 3G/WIFI, Bluetooth, camera, audio/video players and other sensors, characteristics that have made these devices be rapidly adopted in education with the aim of facilitating the creation of ubiquitous m-learning activities [1, 2, 3, 4]. As Jeng et al. explain in their paper [5], mobile technologies offer the possibility of designing different types of learning activities. These authors distinguish between: (1) "*everywhere/everytime activities*" these activities benefit from the ubiquitous mobility that smart phones have; and (2) "*Located*" activities which have to take place in a specific physical space related with the Educational Resources.

This paper studies the aspects that have to be considered when designing *located m-learning activities*. Nowadays different mobile and handheld devices are used with educational purposes, but this paper studies the use of smart phones. The different functionalities that smart phones have can be used to design a learning activity associating spaces and objects of the physical world with the virtual world. The constraints of the physical space are very important when designing *located m-learning activities*. Considering previous located learning activities done by researchers in this field [6, 7, 8, 9, 10, 11], a located m-learning activity can be performed into two big categories of spaces: indoors or outdoors.

Depending on the space selected the technology used to carry out the activity may change. For instance, when a specific space is selected for doing an activity the next step is to think about how we can associate this space with the ERs. As an example, if the space selected is outdoors in an isolated natural park of a mountain, then as a consequence it is not possible to use 3G connectivity for accessing to the educational resources.

We state that the *Space* and the *Connectivity* are the two main factors that affect in the way of designing a located m-learning activity. The combination of these factors, have to be considered for: (1) selecting the adequate *position-based technology* that facilitates the accessibility to the ERs (actions that students have to do for finding these resources and interacting with them) and (2), to identify the best method to *guide* the students though the selected space during the activity.

The aim of the paper is to provide the main factors and considerations to assist practitioners (learning designers or teachers) with the design of m-learning located activities. These factors are down-to-earth since we have been extracted them from the analysis and implementation of real learning situations iteratively designed with teachers and carried out by students in diverse located spaces with different characteristics. Four scenarios are presented, these consider the resulted four combinations between the possible values of the *Space* and the *Connectivity* factors, and the implications that this combination has over the design of the activity. First, we present an indoor located m-learning activity with internet. This scenario occurs typically in a building where we can have a control over the objects and different spaces of the selected area. As an example a real located m-learning activity carried out in a museum is presented [12]. The second scenario presents an indoor m-learning activity where we do not have the possibility of using Internet. The activity "Discovering the campus" [13] done with real students is explained in order to analyze the design factors considered for facilitating the exploration of located ERs related with the campus of an university. The third scenario presents the "Discovering Barcelona!" activity [14]. This was an outdoors m-learning activity where Internet was used. Students explored the city answering geolocated questions for learning about town-planning. Finally in the fourth scenario, an outdoors activity without internet connection is analyzed. This scenario presents the design factors considered for doing an activity for learning botany with smart phones in a natural park where there is not 3G coverage. This activity was done by the authors of this paper but it has not been published yet.

The paper is organized as follows: in Section 2, we detail the space-aware design factors that have to be considered when designing located m-learning activities. Section 3 presents the four types of located m-learning scenarios which can be designed. Finally, Section 5 includes a final discussion, the main conclusions and the future work derived from the contributions of this paper.

II. SPACE-AWARE DESIGN FACTORS

In this section are identified and defined the necessary factors for designing *located m-learning activities*.

- **Space:** physical space where is conducted the located m-learning activity. There exist two categories:
    - **Indoors:** closed physical space determined by the constraints of architectural components, such as walls, doors, corridors, floors, and stairs [15]. E.g.: a museum, a classroom, a building, etc.
    - **Outdoors:** open physical space not determined by the constraints of architectural components. E.g.: a city, a natural park, etc.

- **Connectivity:** Way of connecting with the educational resources, it is dependent on the internet connection of the device or the internet coverage of the space selected.
    - **Internet:** when Internet (3G or WIFI) can be used, the ERs can be stored on the cloud (Link Resources).
    - **No Internet:** when it is not possible to have Internet connectivity, the ERs have to be stored locally on the smart phone (Local Resources).

It is necessary to remark that it would be also possible to prepare an Intranet in a specific space. The case of preparing an Intranet has some similarities and differences with the case of preparing an Internet connection. In both cases the ERs are located in a server (or various external servers in the case of Internet). The important similarity is the fact that the ERs are saved out of the mobile phone. The main difference is that in some spaces (outdoors or indoors) is impossible or very expensive to install an Intranet. For instance, it is very expensive to install an intranet in a route done in a district of a city. For this reason, the paper use the term Internet (assuming that an Intranet can be used only in the case of having permissions for installing the necessary technologies).

- **Guidance:** map showing the different locations that have to be explored following (or not) a route.
    - **Cloud Map:** the map is located on the cloud and it can be updated considering the real position of the smart phone.
    - **Local Map**: Paper map or digital map saved locally on the smart phone.

See an example of the both possibilities in Fig. 1.

Figure 1. Examples of (a) Cloud Map and (b) Local Map

The main benefits of using Cloud Maps are that this type of maps can be updated constantly with new layers of information from Internet. In addition, using a Cloud Map, the student and the teacher can visualize at the same time the information that is happening during the activity. For this reason, cloud maps can be used only when the smart phone has Internet connection. The most common use of Cloud Maps is in an outdoors activity when it is easy to find a map of the space selected. On the other hand, when local maps are used, practitioners can choice between (1) using a digital map saved in the smart phone or (2), using a paper map. Practitioners will have the opportunity of combining local maps (for instance a paper map) and cloud maps if they think that it can facilitate the guidance to their students.

When digital maps (saved in local or in the cloud) are used, the map can provide additional information to guide the student and facilitate their research of ERs. In the case of paper maps, it is necessary that students apply their own strategies to find the ERs.

- **Position-based Technology:** technology used to associate ERs and the activity description with specific physical positions. The main aim is to add layers of information to a particular physical space or an object to augment the information of such as space [17, 18].
    - **GPS coordinates/ Bluetooth** can be used to associate an ER with a position. In the case of using GPS a specific Latitude and Longitude is associated to an ER. Smart phones with GPS and Internet can compare their position with the position of the ER. In the case of using Bluetooth, a device is located in a place sending constantly a signal with the information of the ER. In both cases (GPS or Bluetooth) when the smart phone is located in the correct place the ER is automatically sent to the smart phone.
    - **QR-Codes or RFID technologies.** These are position-based technologies which have to be placed by a person manually in a specific position. Each codes/tags contain information about a specific ER. This information can be a text message, a link or a path indicating the location of the ER in the smart phone.

An important difference that we want to stress between these two types of Position-based Technologies is on the one hand, the actions that students have to do for being able of interacting with the ERs and on the other hand the accuracy of these position-based technologies. In the first case (GPS/Bluetooth) students receive the ER without doing anymore than exploring the space established in the located m-learning activity. In this case, the technology used forces the students to see in the smart phone the ER when they are located in one of the ER-points of the activity. In the case of using Codes or Tags it is necessary that students interact with a physical object (e.g. a QR-Code printed in a paper, a NFC tag) showing their *intention of interaction* for revealing the content related to the ER. Students have to activate a specific functionality of the smart phone (a QR-Code scanner or NFC reader) and then they are able of accessing to the ER.

As Hazas et al. [18] analyzes, RFID and QR-codes have to be used when practitioners need a little accuracy between the student and the position or object selected. GPS or Bluetooth can be used when the distance between the student and the specific location can be higher but the student is capable of distinguishing the specific augmented position/object without problems.

III. INDOORS & OUTDOORS M-LEARNING ACTIVITIES

This section presents four categories of Indoors and Outdoors located m-learning scenarios mediated with smart phones. These categories are the result of combine the *Space* and the *Connectivity* factors. The combination of these two factors will determine the type of guidance and position-based technology used for designing the activity. The examples presented in these scenarios are used as illustrative activities that can be extrapolated to other contexts or educational purposes.

Table 1 indicates the type of *Guidance* and *Position-based Technology* that results from a specific combination of the Space and Connectivity factors.

Table 1. Design Factors for Indoors & Outdoors Learning Activities with smart phones

Space	**Indoors**	X	X		
	Outdoors			X	X
Connectivity	**Internet**	X			X
	No Internet		X	X	
Guidance		**Local Map / Cloud Map**	**Local Map**	**Local Map**	**Cloud Map / Local Map**
Position-based Technology		**Position-based Tags/ Codes or Bluetooth (Link ERs)**	**Position-based Tags/ Codes or Bluetooth (Local ERs)**	**Position-based Tags/ Codes (Local ERs)**	**GPS coordinates or Bluetooth (Link ERs)**

A. *Indoors with Internet*

This type of activities has to be carried out in a closed space with WIFI connection or 3G signal. A typical context is a museum where students have to explore the different rooms and learn about pictures, sculptures, etc. Normally it is a space where it is easy to have a control. This means, that QR-codes, NFC tags or Bluetooth devices can be located in different locations of the space selected (e.g. the museum). It is not necessary to save the ERs in the memory of the smart phone, students can read the corresponding code/tag or receive a link using the Bluetooth and accessing via Internet to the ER. This means that ERs can be changed even when the activity is carried out and also that the teacher can monitor in real time the progress of the students. For instance, the teacher can know when a student is looking at a specific picture.

UbiCicero [12] is a mobile device (a PDA) with an RFID reader and a Local Map (a digital map saved in the device) for guiding students inside a museum. The device detects the tagged artworks and show in the screen over a map, the corresponding positioned ERs. The map shows the different rooms and objects that students have to explore. This means that previously the teacher (or author of the activity) prepared the ERs and associated those to a corresponding RFID positioned using a unique ID in a specific artwork. When visitors were closed to an augmented artwork, the device considered the user position and their behavior history and the nearest ER is showed. When an ID is detected the student has access to read the corresponding ER (it can be a link to a web page with information about the author of the artwork). The device was used in two different museums, improving the visitors' experience by extending their interaction with exhibits.

B. *Indoors without Internet*

Activities with these factors occur typically inside a building where students have to explore different spaces. In some occasions, because of the characteristics of the space it is not possible or very difficult to have Internet connectivity. In this case, it is necessary to save the ERs locally in the memory of the smart phone. The most adequate position-based technologies in this case are: (1) QR-Codes/RFID or (2) Bluetooth.

(1) Using QR-codes/RFID means that before doing the activity all the material have to be saved by the teacher inside all the smart phones, and it is necessary to know the path where each ER is located. We can use QR-Codes if our smart phone has QR-Code scanner. On the contrary, we will use RFID tags if our smart phone has a RFID lector.

(2) On the contrary, when Bluetooth is used it is necessary to distribute the devices (e.g. a laptop sending a signal constantly) with the ER saved in each device. When the smart phone is closed to one of the devices, a signal is received and the ER can be transferred.

An example of learning activity compliant with these characteristics was the activity titled "Discovering the campus!" carried out by Pérez-SanAgustín et al. in [13]. The main objective of this activity was to explore the different spaces and buildings of a constrained campus, in order that novice students discover their context of study. In this case the mobile phones used did not have Internet connectivity. The campus is a closed space where it is possible to distribute NFC tags without running the risk of losing the tags. The authors of the paper saved the ERs inside each mobile and associate a specific path with a NFC tag. When the NFC reader of the mobile phone was activated and closed to the NFC tag, the corresponding ER was opened in the screen of the mobile phone. The students have to do the *intention* of touching the NFC tag in order to read the ER. Each group of students had a paper map (see Fig. 2). This map indicated the spaces that they have to explore, and the number of tags that they can found in each building. Students used the map to guide themselves inside the campus. In this case, each smart phone generated a log containing the information related with the actions done by the students during the activity. The application BT Bridge, based on Bluecove Project [REF], was developed to connect the smart phones with the teachers' computer and extract the information of the log files. For instance, the log saved the order and the time of each read NFC tags. This information was used by the teacher after the activity to analyze the behavior of the students during the ubiquitous activity.

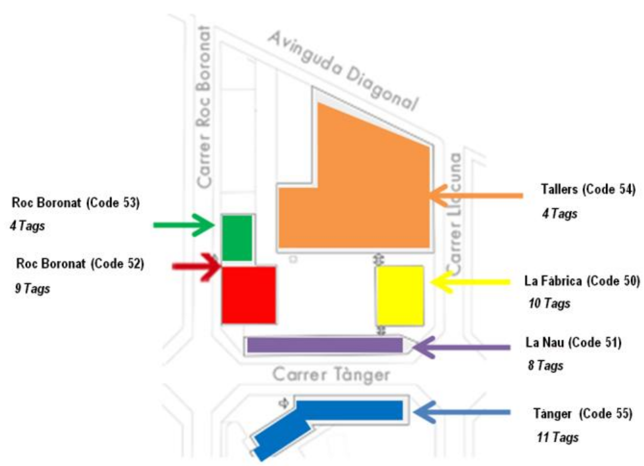

Figure 2. Map for Discovering the campus

C. *Outdoors with Internet*

This scenario takes place typically in a city or in a natural park closed to an urban area. This means that it is possible to have a good 3G and GPS coverage. In this case the ERs can be located in the cloud, and each ER has to be associated to a specific GPS coordinate. Having the ERs saved in the cloud means that teachers can do changes even when the activity is carried out by the students. This is an advantage because an activity done in an outdoors space, such as for example a city, represents a big area that have to be explored and it would be impossible or very difficult to check if tags/codes or Bluetooth devices are still in the correct place when students are doing the activity. The guidance can be done with a cloud map, showing the current position of the student and the position of the closed ERs (in the case of open routes) or the position of the next ER (in the case of sequential routes).

Another alternative is to use Bluetooth position-based technology. However in the case of using this type of technology is advisable to put the Bluetooth devices in places where we will be sure that other people cannot manipulate the devices.

An example of learning activity that illustrates this type of scenario is the activity titled “Discovering Barcelona” done by Santos et al. in [14]. The educational purpose of this activity was to learn about Barcelona’s town-planning. Different educational routes where created with the QuesTInSitu system (described in detail in the cited paper). QuesTInSitu is an authoring tool used to associate QTI Questions with GPS coordinates, creating a route of questions. The teacher created a total of six routes and the students were grouped in different teams. Each team was equipped with a smart phone with GPS and Internet connectivity (see Fig. 3). In this case, they carried out a Paper Map, but a Cloud Map indicating the position of the students and the position of the ERs could be used. When students were near of the position of a QTI question, it appeared automatically in the smart phone. Meanwhile students were doing the corresponding routes, the teacher was monitoring the activity using a computer and the QuesTInSitu system. Thanks to the Internet connectivity the teacher monitored the progress of their students (positions, scores obtained) in real time.

Figure 3. Students participating in the Discovering Barcelona activity

D. Outdoors without Internet

A located m-learning activity outdoors without Internet occurs when the area selected for doing the activity has a bad or null 3G coverage and it is expensive (or impossible) to prepare a WIFI environment. In order to select the adequate position-based technology it is advisable to have into account the characteristics of the area which is going to be explored. When it is possible to have a control over the area, then we can put physically in the desired positions QR-codes or NFC-tags. On the contrary, if it is very difficult to have a control over the area, then it is better to use a paper-map with QR-Codes in the positions where we want that students will access to the corresponding ERs. In case of using this type of map, we cannot be sure that students will be in the correct position when they do the *intention* of reading the QR-code.

The activity titled “Discovering St. Llorenç” carried out by the authors of this paper is an example that illustrates this type of scenario. In this activity a teacher designed an exploratory route for learning botany *in situ*. Due to the characteristics of the natural park, it was not possible to have 3G coverage. In addition it was impossible to distribute NFC-tags or QR-codes physically in the area because it was a protected zone and uncontrolled, in the sense that we cannot guarantee that the QR-codes or NFC-tags will remain in the specific places that were situated in right conditions (e.g., see eventual weather effects). The solution was to create a paper-map of the zone with QR-codes associated to different positions (see Figure 1 (b)). When students believed that they are in the correct position they scanned the QR-Code and accessed to the local ER saved in the smart phone. Then they observed the environment and did the action related with the content of the ER. Once the ER was read they continued with the route. In this case any monitoring system was used, however the monitoring only could be possible after doing the activity.

Fig. 4 illustrates how students explore the natural park using their smart phones.

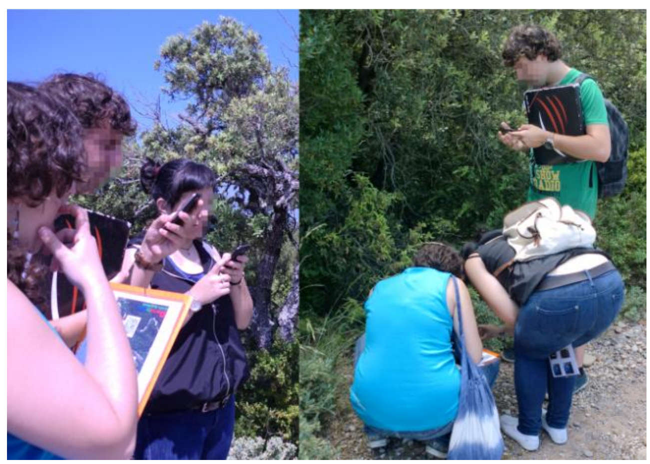

Figure 4. Students participating in the Discovering St. Llorenç activity

IV. Discussion and Conclusion

This paper has proposed four space-aware factors (the space, the connectivity, the position-based technology and guidance) aiming to facilitate practitioners the design of located m-learning activities. These factors have been identified after studying experiments done by other authors, but also have been mainly extracted from the own experience doing and evaluating this type of activities with real students and teachers. The paper shows that the combination of these factors allows the creation of four different located m-learning scenarios supported with smart phones. These scenarios are the result of combining the *Space* and the *Connectivity* factors.

The paper shows how the work done before doing the activity with real students (the design) implies to identify the characteristics of the *Space*. These characteristics are critical to know how to *connect* specific positions with the corresponding educational resources. As the scenarios have presented the ERs can be located on the cloud or locally in the specific device. In the case of using NFC/RFID tags, QR-codes or Bluetooth the preparation of the activity entails more time due to: (1) the practitioner has to prepare the tags/codes or Bluetooth devices and putting them in the corresponding location, and (2) saving the ERs locally in the smart phone or saving them in the corresponding Bluetooth device. In the case of having Internet connection, the ERs can be saved in the cloud, this means that practitioners can change this educational material even when the students are doing the activity.

Then, the *Space* and the *Connectivity* determine on the one hand, the type of *Position-based Technology* (QR-Codes/NFC/RFID tags/ Bluetooth/GPS) that is going to be used to interact with the ERs. As has been identified in the scenarios, in the case of QR-Codes or NFC/RFID tags students have to do an *intentional interaction* to visualize the ER. On the contrary with Bluetooth or GPS technologies, the ER appears automatically when students are closed to the corresponding location. On the other hand, these two main factors (the *Space* and *Connectivity*) also influence in the way that practitioners want to *guide* their students during the located m-learning activity. Practitioners have to select the most adequate map (cloud map or local map) depending on the type of guidance that is desired: with cloud maps the guidance can be enriched with updated information in real time, with local maps if students need more information they have to apply their own strategies (e.g. talk with people around asking about specific places) to achieve the necessary data.

During the activity it is important to collect the actions done by the students, in order to use this information for helping them on real time, for analyzing the progress of the activities or for having this information into account in post-activities (*monitoring* the activity). When it is not possible to have an Internet connection, then it is necessary to implement a log files system activated it in the smart phone. However, in this case, the data collected can be only analyzed after doing the ubiquitous activity. On the contrary, if Internet can be used during the activity, practitioners can receive information from their students in real time (e.g. time of access to the ERs, results, students' positions) and this information could be used to make changes or adapt the activity meanwhile it is done by students.

The scenarios presented in this paper through the space-aware design factors proposed, can be used by practitioners to categorize or envisage their own activities according with their characteristics. As future work, these space-aware factors could be included in a recommender authoring tool with a mash-up of applications with the aim of recommending the most adequate system (or cluster of applications) for implementing located m-learning activities supported with smart phones.

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