Designing for Mobile Learning in Museums

ABSTRACT

This chapter discusses the design challenges of mobile museum learning applications. Museums are undoubtedly rich in learning opportunities to be further enhanced with effective use of mobile technology. A visit supported and mediated by mobile devices can trigger the visitors' motivation by stimulating their imagination and engagement, giving opportunities to reorganize and conceptualise historical, cultural and technological facts in a constructive and meaningful way. In particular, context of use, social and constructivist aspects of learning and novel pedagogical approaches are important factors to be taken in consideration during the design process. A thorough study of existing systems is presented in the chapter in order to offer a background for extracting useful design approaches and guidelines. The chapter closes with a discussion on our experience in designing a collaborative learning activity for a cultural history museum.

INTRODUCTION

Use of mobile devices spreads in everyday human activities. These devices offer portability, wireless communication and connectivity to information resources and are primarily used as mobile digital assistants and communication mediators. Thus, it is of no surprise that various attempts to use mobile appliances for learning purposes have been reported either inside or outside school (Roschelle, 2003). The term *mobile learning* or *m-learning* has been coined and concerns the use of wireless technologies, portable appliances and applications in the learning process without location or time restrictions. Practitioners' reports (Vahey & Crawford, 2002; Perry, 2003) and scientific findings (Roschelle, 2003; Norris & Soloway, 2004; Zurita & Nussbaum, 2004) communicate promising results in using these applications in various educational activities. The related bibliography proposes various uses of mobile appliances for learning. These Activities might concern access and management of information and communication and collaboration between users, under the frame of various learning situations.

A particular domain related to collaborative learning is defined as the support provided towards the educational goals through a coordinated and shared activity (Dillenbourg, 1999). In such cases, peer interactions involved as a result of the effort to build and support collaborative problem solving, are thought to be conducive to learning. On the other hand, traditional groupware environments are known to have various technological constraints which inflict on the learning process (Myers et al., 1998). Therefore, mobile collaborative learning systems (mCSCL) are recognized as a potential solution, as they support a more natural cooperative environment due to their wireless connectivity and portability (Danesh, Inkpen, Lau, Shu, & Booth, 2001). While the mobility in physical space is of primary importance for establishing social interaction, this ability is reduced when interacting through a desktop system. It is evident that, by retaining the ability to move around it is easier to establish a social dialogue and two discrete communication channels may be simultaneously established through devices: one physical and one digital. Additionally, a mobile device can be treated as an information collector in a lab or in an information rich space (Rieger & Gay, 1997), as a book, as an organizing medium during transportation or even as a mediation of

^ This is an early draft of a chapter to appear in a multi-authored volume on User Interface Design and Evaluation for Mobile Technology. To be quoted as follows:
N. Tselios, I. Papadimitriou, D. Raptis, N. Yiannoutsou, V. Komis, N. Avouris (2007), Designing for Mobile Learning in Museums, in J. Lumsden (ed.), "Handbook of Research on User Interface Design and Evaluation for Mobile Technology", Idea Group Publishers.

rich and stimulating interaction with the environment (i.e. in a museum). Effective usage of mobile appliances has been reported in language learning, mathematics, natural and social sciences (Luchini et al., 2002).

Furthermore, various technological constraints need to be taken in consideration during the design of activities which involve mobile devices. Such an example is the small screen which cannot present all the information of interest while the lack of a full keyboard creates constraints in relation to data entry (Hayhoe, 2001). There is a need to provide the user with the possibility to 'go large' by getting information from both the virtual and physical world, while simultaneously 'going small', by retrieving the useful and complementary information and getting involved into meaningful and easy to accomplish tasks (Luchini et al., 2002). In addition, despite the fact that technological solutions are proliferating and maturing, we still have a partial understanding of how users take effectively advantage of mobile devices. Specifically, in relation to communication and interaction, we need to investigate how mobile technology can be used for development of social networks and how it can provide richer ways for people to communicate and engage with others. In public spaces, like museums, a crucial question is if the serendipitous exchanges and interactions that often occur should be supported through mobile technology, how and where the interaction between people takes place and how is affected by this novel technology. Clearly, a better understanding of social activities and social interactions in public spaces should emerge to answer these questions.

A number of the aforementioned issues are discussed next in the context of a museum visit. First, we analyse how the context can affect any activity and application design. Then, we outline the most promising mobile learning applications and finally, we present our experiences of introducing collaborative learning activities using a novel approach based on the best practices surveyed previously, in a large scale project for a cultural history museum.

INTERACTION DESIGN FOR MOBILE APPLICATIONS

Interaction design is one of the main challenges of mobile applications design. Direct transfer of knowledge and practices from the user-desktop interaction metaphor, without taking in consideration the challenges of the new interaction paradigm is not effective. A new conceptualization of interaction is needed for ubiquitous computing. The traditional definition (Norman, 1986) of the user interface as a "means by which people and computers communicate with each other", becomes in ubiquitous computing, the means by which the people and the environment communicate with each other *facilitated* by mobile devices. As a result, interaction design is fundamentally different. In the traditional case, the user interacts with the computer with the intention to carry out a task. The reaction of the computer to user actions modifies its state and results in a dialogue between the human and the machine.

On the other hand, the user interaction with mobile devices is triadic, as the interaction is equally affected not only by the action of the user and the system's response, but by the context of use itself. The level of transparency of the environment, taking into account the presence of the mobile device and the degree of support to 'environmental' tasks meaningful to the user, are new issues to be considered. Consequently, new interaction design and evaluation criteria are required, since the design should not only focus on the user experience but pay also attention to the presence of other devices or objects of interest, including the level of awareness of the environment. By building the virtual information space into the real, the real is enhanced, but conversely, by drawing upon the physical, there is the opportunity to make the virtual space more tangible and intuitive and lower the overall cognitive load associated with each task.

To summarize, a number of design principles are proposed for mobile applications design:
(a) effective and efficient *context awareness* methods and models, with respect to the concept of context as defined by Dey (2001): 'Context is any information that can be used to

characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves'.
(b) presentation of useful information to the user *complementary* to the information communicated by the environment.
(c) a*ccurate and timely update* of environmental data that affect the quality of interaction.
(d) contextualized and personalized information according to *personal needs*.
(e) Information should be *presented to the user* rather than having the user searching for it.

Failure to look into these design issues can lead to erroneous interaction. For example, delays of the network, lack of synchronization between two artifacts of the environment or slight repositioning of the device can lead to misconceptions and illegal interaction states. In addition, information flow models should be aligned according to the information push requirement and relevant user modeling and adaptation techniques to support this flow of information should be defined. Finally, new usability evaluation techniques, concerning mobile applications should emerge to shape a novel interaction paradigm.

Dix et al. (2000) present a framework to systematically address the discussed design issues and successive context awareness elements are inserted in the design process: (a) the *infrastructure* level i.e. available network bandwidth, displays' resolution), (b) the *system* level (type and pace of feedback and feed through), (c) the *domain* level (the degree of adaptability that a system must provide to different users) and (d) the *physical* level (physical attributes of the device, location method and the environment). All these elements should be tackled independently and as a whole in order to study the effect of every design decision to each other.

We formulate the interaction design aspects discussed through the problem of designing a mobile learning application for a museum. During the visit a user has only a partial understanding of the available exhibits. This situation can be supported by complementary information included in the physical environment, e.g. alternative representations, concerning the historical role of the people or the artifacts presented the artistic value of a painting (Evans & Sterry, 1999), etc. This cognitive process of immersion into the cultural context, represented by the museum exhibits, could be supported by drawing upon the stimuli produced during the visit using context aware mobile devices. Therefore, these devices should be viewed as tools to enhance the involvement of a user in the cultural discovery process, tools that challenge the user to imagine the social, historical and cultural context, aligning her to a meaningful and worthy experience.

It is not argued here that the infusion of mobile technologies in museums will necessarily result to meaningful learning processes. Our analysis involves the potential use of the technology when integrated in educational activities (Hall & Bannon, 2006), which will offer a structured learning activity according to the characteristics of museums' content and the functionalities of the technologies used. To better illustrate this point a) we briefly present a set of selected exemplary cases which demonstrate different ways of integrating mobile educational applications in museums and b) we provide a more detailed account of such an application that we designed for a museum in Greece.

In the next section a number of approaches supporting such a visit are reviewed and examined using the design aspects as guiding paradigm and point of reference. Since the goal of the visitor is to see and learn more and not to explicitly use technology, a deep understanding of visitors' needs is important during the design phase, to avoid disturbances that can destruct her from her objective. Therefore, decisions made for the technology used and the styles of interaction, with the involved devices, have to deal with user's patterns of visit. Having the above requirements in hand, we use the framework proposed by Dix et al. (2000) to organize a coherent characteristics inspection of some representative examples of mobile museum guides.

MOBILE DEVICES AS MUSEUM GUIDES

In this section, some representative design approaches for mobile museum applications are discussed. An extended survey is included in Raptis, Tselios and Avouris (2005). The first system named "Electronic Guidebook", deployed in the Exploratorium science museum (Fleck et al., 2002), tries to involve the visitors to directly manipulate the exhibits and provides instructions as well as additional science explanations about the natural phenomena people are watching. The system of the Marble Museum of Carrara (Ciavarella & Paterno, 2004) stores the information locally in the PDA's memory, uses a map to guide the visitors around the museum and presents content of different abstraction levels (i.e., room, section and exhibit). The "ImogI" system uses Bluetooth to establish communication between the PDAs and exhibits and presents the closest exhibits to the user, (Luyten & Coninx, 2004). The "Sotto Voce" system gives details about everyday things located in an old house (Grinter et al., 2002) by having pictures of the walls on the PDA's screen and asking from the user to select the exhibit she is interested in, by pressing it. The "Points of Departure" system (www.sfmoma.org) gives details in video and audio form by having 'thumbnails' of exhibits on the PDA's screen. It also uses 'Smart Tables' in order to enrich the interaction. A system, in the Lasar Segall Museum, Sao Paolo, Brazil (Dyan, 2004), automatically delivers information to the PDA, about more than 3000 paintings. In the Tokyo University Digital Museum a system uses three different approaches to deliver content. The PDMA, in which the user holds the device above the exhibit she is interested in, the Point-it, in which the visitor uses laser-pointer to select specific exhibits and finally the Museum AR in which visitors wear glasses in order to get details about the exhibits (Koshizuka & Sakamura, 2000).

The system developed in the C-Map project, (Mase, Sumi, & Kadobayashi, 2000), uses active badges to simulate the location of the visitor, allowing tour planning and a VR system, controlled by the gestures of the visitor. In a Tour guide (Chou, C. Lee, M. Lee, & Chang, 2004), the information about the exhibits is automatically presented and there is no variation in the form of the visit, but subjective tour guides are used. A different approach is the one adopted in the Museum of Fine Arts in Antwerp (Van Gool, Tuytelaars, & Pollefeys, 1999), in which the user is equipped with a camera and selects exhibits, or details of an exhibit by taking pictures. A tour guide in the PEACH project, (Rocchi, Stock, Zancanaro, Kruppa, & Krüger, 2004), which migrates the interaction from the PDA to screens and uses a TV-like metaphor, using 'newscasters' to deliver content. Finally, a nomadic information system, the Hippie, developed in the framework of the HIPS project, (Oppermann & Specht, 1999), allows the user to access a personal virtual space during or after the visit. In the latter system, an electronic compass is used to identify the direction of a visitor.

The *infrastructure* context concerns the connections between the devices that comprise the system and influence the validity of the information that is provided through them to the users and needs not only to be addressed in problematic situations. It is also related with the validity and timely updates of available information. This can be clearly seen in collaboration activities where the user constantly needs to know the location of other users, the virtual space, the shared objects etc. In the specific Museum domain the results may not be so critical but can lead the user to various misunderstandings.

The mentioned systems use an indirect way of informing the user that her requests have been carried out: the user sees and hears the reflection of her requests on the PDA. There is no clear notification that the user's demands are executed successfully or not. Some of the systems use external factors, as signs of success, such as a led light ("Rememberer") and audio signals ("Marble Museum"). But in general terms, the user is on her own when problems occur and the systems leave it up to her to find it out, by observing that, there is no progress. We have to point that it could be very distracting and even annoying to have feedback messages in every state of interaction, but it is important for designers, to include a non-intrusive approach to inform that there is a problem and provide constructive feedback to overcome it.

	Awareness technology	**Functionality distribution**	**Information flow**	**Complementary devices**
Rememberer	RFID	Server based	Passive	Cameras
Sotto Voce		Locally stored info	Active	
ImogI	Bluetooth	Info stored in Bluetooth transmitters	Active, proximity manager	
Marble Museum	IrDA	Locally stored info, abstraction levels	Active, history of the visit	
PEACH project	IrDA	Server based	Passive, task migration	Screens
Points of departure		Locally stored info	Active	Screens
C-Map	IrDA	Server based	Active, exhibit recommendations	Active Badges, Screens
Lasar Segal Museum	IrDA	Server based	Passive	
"Antwerp project"	IrDA	Server based	Active	Cameras
Tour Guide System (Taiwan)	IrDA	Server based	Passive, subjective tour guides	
PDMA, Point it, Museum AR	IrDA	Server based	Active, by various means	laser pointer, glasses
Hippie	IrDA	Server based	Active, info presented based on the history of visit	

Table 1. Design decisions affecting system context (from Raptis et al., 2005).

Regarding the *system* context we can distinguish four different approaches as a means of awareness technology. In the first approach (Table 1), the PDA is the whole system. There are no other devices or awareness mechanisms involved and the information presented to the user is stored locally in the PDA. The second approach uses RFID tags to establish communication between the PDAs and the exhibits and the third which uses Bluetooth to establish communication with the exhibits and deliver content. The forth and most common approach uses IrDA technology to estimate the position of the visitor in space. Usually, IrDA tags are placed near every exhibit or in the entrance of each exhibition room and Wi-Fi derives the information to the PDA from a server Also, many different additional devices are built and integrated into these systems like screens (as a standalone devices or as interacting devices with the PDAs, where the user has the opportunity to transmit sequentially her interaction with the system from the PDA to a Screen). Regarding the *location*, all the studied systems use a topological approach to identify the position of a PDA, which informs approximately the system about the user's location. However, in the case of a museum with densely place exhibits, a more precise Cartesian approach can yield accurate user localization.

Domain context concerns aspects related to the situated interaction that takes place in the specific domain. Often in museum applications there is a lack of information about user profiles and characteristics. It is however important to consider that each visitor in a museum has different expectations, and is interested in different aspects regarding the exhibits. In the studied systems only in those that allow interaction of the users with servers there is a possibility for personalized interaction. Most of the systems require from the user to login, answer some specific questions, in order to build a model of the user and present the information in her PDA according to her language, her expertise level and her physical needs (i.e. bigger fonts for those with sight impediments). When domain context is absent from the design process the system operates as a tool suited for the needs of a single hypothetical 'ideal' user. In such an environment this 'ideal' user will likely represent the needs and expectations of a small fraction of real visitors.

The system may push information to the user or it may wait until the user decides to pull it from the system. In the first case, special consideration should be taken to the user's specific activity and objective. Questions related to situated domain context are the following: Does the system propose any relevant information based on the history of users interaction? Does it adapt to actions repeatedly made by the user? Does it present content in different ways? For example, the "ImogI" system rearranges the order of the icons putting in front the mostly used ones. Also, in PEACH and in 'Points of Departure' the user can change the interaction medium from PDAs to Screens, in order to see more detailed information.

The *physical* context lays in the relation of the system with the physical environment and in problems concerning the physical nature of the devices. However, in the studied systems there is not a single mechanism of identifying the physical conditions. For example, in a room full with people, where a lot of noise exists, it would be appropriate if the system could automatically switch from an audio to a text presentation.

From the survey of the mobile guides applications presented here it seems that efficient design approaches could be achieved by augmenting physical space with information exchanges, by allowing collaboration and communication, by enhancing interactivity with the museum exhibits and by seamlessly integrating instantly available information delivered in various forms. However, the synergy between technology and pedagogy is not straightforward especially if we take into account the need to tackle issues such as efficient context integration, transparent usage of the PDA, and novel pedagogical approaches to exploit the capabilities of mobile devices. As a result, after discussing in detail usages of a mobile device as a mean of museum guidance, in the following, we attempt to discuss explicit educational activities mediated by mobile devices and a specific example of a new Mobile Learning environment.

DESIGNING MUSEUM MOBILE EDUCATIONAL ACTIVITIES

The level of exploitation of mobile devices in a museum setting is increasing and part of this use may have educational value. In this section we will focus on the added value of integrating educational mobile applications in museums. We will start our analysis by posing two questions that we consider central to this issue: (a) what is changing in the learning process taking place in a museum when mediated by mobile technology and (b) why these changes might be of educational or pedagogical interest? We will attempt to address these questions by focusing on three aspects related not only to the characteristics of mobile technology but also to the results of its integration in a museum. Specifically we will discuss: a) the types of interaction between the visitor and the learning environment (e.g., the museum), b) the learning activities that these interactions can support and c) the role of context and motion in learning.

One facet of the learning process when mediated by mobile technology in museum visits involves the tangibility of museum artifacts: distant museum exhibits that were out there for the visitors allowing them just to observe now can be virtually touched, opened, turned and decomposed. In this case, technology provides to the user the key to open up the exhibit, explore it and construct an experience out of it. The traditional reading of information and observation of the exhibit is considered as one-dimensional “information flow” from the exhibit to the user. Mobile technology facilitates the transformation of the one dimensional relationship to a dialectic relationship between the user and the exhibit. Furthermore, this relationship can now include another important component (apart of the exhibits) of the museum environment: the other visitors. By providing a record of user –exhibit interaction for other visitors to see, reflect upon and transform technology can support social activities of communication, co-construction etc., between the visitors. To sum up, mobile technology mediates three types of interaction between the learner and the learning environment of a museum: a) “exhibit – user” interaction b) “user – exhibit” interaction and c) “between the users” interaction about “a” and “b”.

The enrichment of interaction between the learner and the museum might result in more or different learning opportunities (Cobb, 2002) the characteristics of which are outlined here. Specifically, the dialectic relationship between the user and the museum artifacts, mediated by mobile devices, might offer chances for analysis of the exhibit, experimentation with it, hypothesis formulation and testing, construction of interpretation, information processing and organization, reflection and many more, according to the educational activity designed. Collaboration and communication about the exhibits and information processing about them makes possible socio-constructive learning activities. By comparing these elements of the learning process to the reading or hearing of information about the exhibits (which is a the starting point for a non technology mediated museum visit) we realize that mobile technology has the potential to offer an active role to the learner: she can choose the information she wants to see, open up and de-construct an exhibit if she is interested in it, see how other visitors have interacted with a certain exhibit, discuss about it with them, exchange information, store information for further processing and use and so ont.

Up till now we described the role of mobile technology in learning with respect to two characteristics of the museum as learning environment: the exhibits and the other visitors. Another characteristic of the museum, which differentiates it from other learning environments (e.g. classroom) is that learning in a museum takes place while the learner moves. Learning while moving, quite often takes place very effectively without the support of technology. However there are cases that further processing with appropriate equipment is needed or some structuring of this “mobile learning experience” is proved to be useful. Mobile technologies can find in museums an important area of implementation not only because museum visits are structured around motion but because we have to support visitors *during* and not just after or before the visit (Patten, Arnedillo Sanchez, & Tangney, 2006). But why is it important to support learning during the visit? The answer here comes from the theory of situated learning (Lave & Wenger, 1991) which underlines the role of context in learning. Specifically, context facilitates knowledge construction by offering the practices, the tools, and the relevant background along with the objectives towards which learning is directed and has a specific meaning or a special function (knowledge is used for something). Finally, the use of mobile devices provides a new and very attractive way of interacting with the museum content especially for young children (Hall & Bannon, 2006).

As mentioned previously a large number of mobile applications have been developed during previous years for use in the museums (Raptis et al., 2005). All these mobile applications can add educational value to a museum visit in various ways. A survey of mobile educational applications for use inside the museum, led us to a categorization according to the educational approach followed in every occasion. The first category includes applications that mainly deliver information to the visitor and concerns the vast majority of applications created for museums. Mobile devices take the place of the museums' docents and offer predetermined guided tours based upon certain thematic criteria. The aforementioned applications offer the museum visitor an enhanced experience which can support the learning process through a behaviourist approach. Enhancement is succeeded by supplying multimedia and context-related content.

The second category of applications, suitable for educational use in museums, consists of applications which provide tools that can support the learning process in a more profound way. Compared to the first category, they provide information about the exhibits of a museum but furthermore they include a series of functions that increase the interactivity with the user. Such an example is the Sotto Voce System (Grinter et al., 2002), which includes an electronic guide with audio content and the ability of synchronized sharing of this content between visitors. Thus, the users can either use individually the guide or "eavesdrop" to the information that another visitor listens.

Another example is the applications developed for the Exploratorium, a science museum in San Francisco (Fleck et al., 2002). In this museum, the visitor has the possibility to manipulate and experiment with the exhibits. Also, an electronic guidance was designed to provide information about the exhibits and the phenomena related with them, posing relative questions to provide deeper visitors' engagement. These applications are closer to social-cultural learning theories as they provide the user with tools to organize and control the provided information.

The third category of educational applications presents a specific educational scenario. Usually, game-based activities where the users, mostly children aged 5-15, are challenged to act a role and complete carefully designed pedagogical tasks. Such an example is the MUSEX application (Yatani, Sugimoto, & Kusunoki, 2004), deployed in the National Museum of Emerging Science and Innovation in Japan. MUSEX is a typical drill and practice educational system in which children work in pairs and are challenged to answer a number of questions. Children select an exhibit with their RFID reader equipped PDA and a question is presented in the screen with four possible answers. The activity is completed when each pair collects twelve correct answers. Children may collaborate and communicate either physically or via transceivers and monitor each group progress through a shared screen. After the completion of the activity the participators have the possibility to visit a website and track their path inside the museum. The users can deeply interact with the exhibits, review the progress of her partner or ask for help (Yatani et al., 2004).

DinoHunter project includes several applications for the transmission of knowledge through game-based and mixed reality activities in the Senckenberg museum, Frankfurt, Germany. Three of these applications, namely DinoExplorer, DinoPick and DinoQuiz, are being supported by mobile technologies (Feix, Gobel, & Zumack, 2004). DinoExplorer delivers information to the users as an electronic guide, DinoPick allows the users to pick one part of the body of a dinosaur and get more multimedia information about this specific part and DinoQuiz provides a set of questions for further exploration of the exhibits of the museum.

Mystery at the Museum is another mobile, game-based, educational activity created for the Boston Museum of Science. It engages visitors in exploring and thinking in depth about the exhibits, thus making connections across them and encourages collaboration (Klopfer, Perry, Squire, Jan, & Steinkuehler, 2005). High School students and their parents are called to solve a crime mystery where a band of thieves has stolen one of the exhibits. The users try to locate the criminals by using a PDA and a walkie-talkie. The participants must select upon the role of a technologist, a biologist or a detective. Depending on the chosen role they can interview virtual characters, pick up and examine virtual objects by using virtual equipment (e.g. Microscope), collect virtual samples via infrared tags or exchange objects and interviews through the walkie-talkies. A study confirmed deep engagement of the participants and extensive collaboration due to the roles set.

Another similar approach is presented through the Scavenger Hunt Game activity used in the Chicago Historical Society Museum (Kwak, 2004). In this case, the children are challenged to answer a series of questions related to the exhibits and the local history. They undertake the role of a historical researcher and they are called to answer ten multiple choice questions while examining the exhibits. Each user is individually engaged into the activity and her progress is evaluated in a way similar to electronic games. The Cicero Project implemented in the Marble Museum of Carrara introduces a variety of games to the visitors (Laurillau & Paternò, 2004). The games vary from finding the missing parts of a puzzle to answering questions about the exhibits. Its main characteristic is the support it provides to the visitors to socially interact and collaboratively participate in activities concerning the exhibits of the museum, through peer-awareness mechanisms.

A series of mobile educational activities was also carried out in the frame of the Handscape Project in the Johnson Museum (Thom-Santelli, Toma, Boehner, & Gay, 2005). The "Museum Detective" engage students in role-playing activities. Children working in pairs are called to locate an object described by one clue and learn as much as possible for it. A series of multiple-choice questions is presented for further exploration of the exhibit. Four types of interactive element are also provided for the exhibits: a painting, a drawing activity and a building activity and a multimedia narrative. The multiple-choice questions and the building activity were drill and practice activities and the rest were activities allowing children to make their own creations.

The systems of the latter category present coherent learning experiences comprised of planned and organized pedagogic activities, where an intervention has been purposefully designed to result a positive impact on children's cognitive and affective development. With respect to the contextual and interaction issues presented in the previous sections, we attempt to present in the next section an integrated application that involves children as role-playing characters by exploring the museum using a PDA.

AN EXAMPLE OF MOBILE ACTIVITY DESIGN FOR INDOOR MUSEUM VISIT

The "Inheritance" activity discussed here, is designed to support learning in the context of a cultural/historical museum visit. The application involves role-playing, information retrieval, data collecting and collaboration educational activities, suitable for children aged 10 or above working in teams of two or three members each. The activity scenario describes an imaginary story where the students are asked to help the Museum in finding the will of a deceased historian, worked for years in it. This will is hidden behind the historians' favourite exhibit. Clues to locate the document are scattered among the descriptions of some exhibits. If the children manage to find the will, all of the property of the historian will be inherited by the museum and not by his "greedy relatives". The scenario urges the students to read the description of the exhibits, find the clues and collaboratively locate the specific one.

During the design process of the activity we had to study the *museum context*, the *mobile technology* used and the *learning approach* to be followed in order to achieve the desired pedagogical outcome. The survey discussed in the previous section led us to adopt the following interaction design decisions. A PDA with wireless network capability is used and an RFID reader is attached to it to 'scan' the RFID tags used to identify the exhibits. Wi-Fi infrastructure is being used to deliver data and establish communication between the visitors. When an exhibit is scanned, the PDA sends a request for information to the server which delivers the appropriate content presented in the form requested by the user. Data exchange between two users is accomplished through alignment of their devices while pointing one to the other, which mimics the exhibit scanning procedure. We also opted for small chunks of text since reading at low resolution screens reduces reading comprehension significantly.

The educational design of the activity was inspired by the social and cultural perspective of constructivism. It was structured around a set of learning objectives relevant to the thematic focus of the museum, to the exhibits' information, to the age and previous knowledge of the students, and to the fact that involves a school visit (as opposed to individual museum visits). The basic elements which shaped the activity were:

a) Engagement of interest: Engagement and interest hold an important role in the learning process. Student interest in a museum should not be taken for granted, especially because a visit arranged by the school is not usually based on the fact that some students might be interested to the theme of the museum. In the inheritance activity we considered to trigger student interest by engaging them in a game. The setting, the rules and the goal of the game were presented in the context of a story.
b) Building on previous knowledge: The focus of the activity was selected with respect to the history courses that students were taught in school. They had a general idea about the specific period of the Greek history and the activity offered complementary information about certain issues of this period. Building on previous knowledge was expected to support students in problem solving and hypothesis formulation and testing.
c) Selecting – processing – combining pieces of information The scenario is structured around the idea that students read the offered information, select what is relevant to their inquiry and combine it with other pieces of information that have selected and stored earlier. Thus the students are expected to visit and re-visit the relevant exhibits, go through the information that involves them as many times as they think necessary and not just retrieve that information but combine it and use it in order to find the favourite exhibit which is the end point of the game
d) Hypothesis formulation and testing: When students have selected enough information from the exhibits around one room of the museum they can attempt to use some of the clues they have selected in order to find the favourite exhibit. If they fail they can go around the room to collect more information and try again.
e) Communication and collaboration: The activity is designed to facilitate inter and intra-group collaboration. Specifically, two groups of students are expected to collaborate to determine which exhibit they will interact with, to exchange clues using their PDA and to discuss their ideas about the favorite exhibit.

Figure 1. Screenshots of the “Inheritance” application. (a) dialogue for RFID tags reading (b) information for a selected exhibit (c) clue selection (d) the notepad screen.

During the activity, the participating teams are free to explore any exhibit. Each team is provided with a PDA to extract information related to the exhibits by reading the tags attached to each of the exhibits (Figure 1). Only some of the exhibits contain ‘clues’, which give information about the favourite exhibit to be found. Children must locate them, store them in the PDAs notepad and after collecting all or most of the clues the teams are able to beam their clues to each other. After collecting all six clues the students are challenged to locate the favourite exhibit. When both teams agree that one exhibit is the favourite one, they can check the correctness of their choice by reading with both PDAs the RFID tag of the chosen exhibit.

After the development of a prototype application, a case study was conducted inside the museum in order to validate the design choices. Seventeen students, aged 11, participated in the study (Figure 2). Data concerning all involving elements were collected to study the activity in depth. The activity was videotaped, PDA screen recording has been used and voice recorders were used to record dialogues among the participants.

Figure 2. Children engaged in the activity

The goal of the data analysis was twofold. First, to identify problems children encountered during the process in relation to each of the activity's elements. Then, to identify the nature of the interactions occurred during the procedure. Our analysis is based on the Activity Theory, concerning mainly human practices from the perspective of consciousness and personal development. It takes into account both individual and collaborative activities, the asymmetrical relation between people and things, and the role of artifacts in everyday life. The activity is seen as a system of human processes where a subject works on an object in order to obtain a desired outcome. In order to accomplish a goal, the subject employs tools, either conceptual or embodiments. Activity is consisted by different components which are (Figure 3): (a) *subject*, (the persons engaged in the activity), (b) *object* (scope of the activity), (c) its *outcome* (c) *tools* used by the subjects (d) *rules-roles* that define the activity process, (e)*community* (context of the activity) and (f)*division of labour* (tasks division among the participants, Kuuti, 1995; Zurita & Nussbaum, 2004).

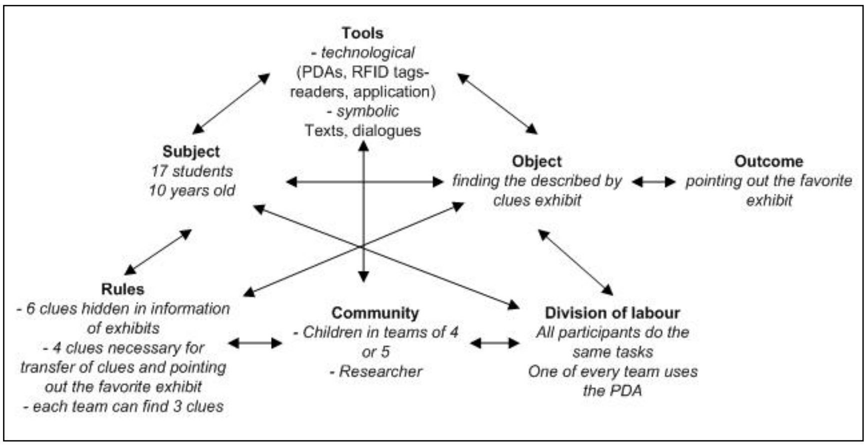

Figure 3. Description according to the Activity Theory Model

Activity Theory is of fundamental importance to deeper understand learning with mobile devices while visiting a museum, since in this case knowledge construction is mediated by cultural tools in a social context. The data collected were analyzed with the use of the Collaboration Analysis Tool (ColAT) environment which supports a multilevel description and interpretation of collaborative activities through fusion of multiple data (Avouris, Komis, Fiotakis, Dimitracopoulou, & Margaritis, 2004).

In our analysis, an activity is a procedure during which objects become knowledge through three different levels-steps. Operation is the lower level where routine processes facilitate the completion of goal-oriented actions which in turn constitute the activity. Dialogues, user operations in the application and observations derived from the videos were transcribed in this first level of analysis. The actors, the operations and the mediating tools were noted in this level. Actors were the two participating teams and the researcher. The mediating tools were the dialogue among children and the researcher, texts of information (symbolic) and the application (technological). Some examples of operations in our case are text scrolling, RFID tag reading and transition from one screen to another. Analysis of these user operations led us to the identification of a problem in the use of the application. For example, due to data transfer delay from the server to the PDA, users in some occasions were frustrated and selected repeatedly an action due to lack of timely feedback.

In the second level, the different actions presented among the structural components of the activity are being studied. In order to identify and categorize the actions, a series of typologies were introduced. Typologies were set according to the goal and the mediating tool of each action. For example when children used the PDA to read the text information (mediating tools) their goal was not always the same. Three different typologies were used to describe the situation when the children read carefully the information provided ("Reading of information"), when they were reading the information and searched for clues also ("Reading and searching for clues"), and finally when they were "Searching for clues only". A "Reading and searching for clues" action example is presented in Table 2. Children scroll down the text and one of them states in the end of this action that they were unable to find a clue. When children search only for clues without paying attention to the information we observe rapid scrolling. A clear indication that they have already found all the clues is when children read only the information.

Time	Actor	Tool	Events
00 : 08 : 50	Group1	PDA	Selection of "read"
00 : 08 : 52	Group1	texts	Information D. Stefanou
00 : 09 : 21	Group1	PDA	scrolling
00 : 09 : 33	Group1	PDA	scrolling
00 : 09 : 38	Group1	PDA	scrolling
00 : 09 : 42	Group1	PDA	scrolling
00 : 09 : 45	Group1	PDA	scrolling
00 : 09 : 49	Group1	PDA	scrolling
00 : 09 : 57	Group1	PDA	scrolling
00 : 10 : 02	Group1	PDA	scrolling
00 : 10 : 03	Group1	Dialogue	It doesn't have any (clues) here

Table 2. An extract of the data analysis presenting action of the 'reading and searching for clues' class

Other actions defined in our study were related to the dialogue between the children and the researcher aimed to overcome difficulties in using the application or understanding the rules-roles of the activity. Typologies where also introduced to describe the interaction between children related to the next step in the procedure (…*"Should we go there? …ok")* and the exchange of thoughts about the solution of the activity (…*"Well, tell me, the first clue is? …He could spy the Turkish army"…)*. In the third level of analysis, patterns identified concerning the evolution of the procedure.

Clearly, the basic goals of the activity as described previously in this section have been fulfilled. Data analysis indicated that children were highly motivated by the activity and collaborated in order to achieve their goal. As derived from the analysis, the teams adopted different strategies to accomplish the task. Collaboration was observed mainly while making the choice of the next exhibit to be examined. After completing the task of finding the clues, the two teams collaborated more closely. They divided the work needed to find the exhibit described by the clues and looked in different parts of the room while collaborating and sharing their thoughts and suppositions. They used the clues as information filters thus eliminating the ones that did not match. Additionally, the learning result of this activity, as derived from subsequent students' essays describing the visit experience, was a deeper understanding of the historical role of the persons represented in the exhibits and their interrelations.

CONCLUSIONS AND FUTURE WORK

This chapter attempted to present current design approaches for mobile learning applications in the context of a museum visit. In addition, thorough study of similar approaches took place, which lead to useful design patterns and guidelines. As discussed, design of mobile learning systems, is not a straightforward process. In addition to the challenge of integrating the concept of context into the design process and independently from context conceptualization, a comprehension of pedagogical goals, desired learning transfers, user typical needs and objectives should take place. We argue that proper design decisions should take into account a solid theoretical cognitive framework, as well as the special characteristics of the mobile devices used and the challenges of such an informal learning setting. A suitable activity should be properly supported by adequate interaction models, deeper understanding of the tasks involved to carry out the activity as a whole and their expectations while carrying out specific actions. For this reason, further validation of our proposed activity, took place in the actual Museum. The activity was enjoyed by the students and enhanced their motivation to learn more about the cultural and historical context represented by the exhibits. The latter challenge has been better illustrated while discussing our experience of designing a collaborative learning activity in a cultural history museum and a case study validating its usefulness.

Clearly, the future of learning technology in museums lies in the blending, not the separation, of the virtual and the real world. That is because learning in a museum context could be conceived as the integration, over time, of personal, socio-cultural, and physical contexts. The physical setting of the museum in which learning takes place mediates the personal and socio-cultural setting. The so called 'interface transparency' should be treated as an effort to seamlessly integrate the computational device to our natural environment. This goal could be achieved by augmenting physical space with information exchanges, allowing collaboration and communication, enhancing interactivity with the museum exhibits and by seamless integrating instantly available information delivered in various forms. However, the synergy between technology and pedagogy is not straightforward, especially if we take into account the need to tackle issues such as efficient context integration, transparent usage of PDA, and novel pedagogical approaches to exploit the capabilities of the mobile devices. Therefore, further research effort should take place to experience established methods and practices.

REFERENCES

Avouris, N., Komis, V., Fiotakis, G., Dimitracopoulou, A., & Margaritis, M. (2004). Method and Tools for analysis of collaborative problem-solving activities.in *Proceedings of ATIT2004, First International Workshop on Activity Theory Based Practical Methods for IT Design* (pp. 5-16). Retrieved on February 28, 2007 from http://www.daimi.au.dk/publications/PB/574/PB-574.pdf

Chou, L., Lee, C., Lee, M., & Chang, C. (2004). A Tour Guide System for Mobile Learning in Museums. In J. Roschelle, T.W. Chan, Kinshuk & S. J. H. Yang (Eds.), *Proceedings of 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education – WMTE'04* (pp. 195-196). Washington, DC: IEEE Computer Society.

Ciavarella, C., & Paterno, F. (2004). The design of a handheld, location-aware guide for indoor environments. *Personal Ubiquitous Computing, 8,* 82–91.

Cobb, P. (2002). Reasoning With Tools and Inscriptions. *The Journal of the Learning Sciences*, *11(2 & 3),* 187 – 215.

Danesh, A., Inkpen, K.M., Lau, F., Shu, K., & Booth, K.S. (2001). Geney: designing a collaborative activity for the palm handheld computer. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems - CHI 2001* (pp. 388-395). New York: ACM Press.

Dey, A. (2001). Understanding and Using Context. *Personal and Ubiquitous Computing Journal*, *5(1),* 4-7.

Dillenbourg, P. (Ed.) (1999). *Collaborative learning: cognitive and computational approaches*. Oxford, UK: Elsevier Science.

Dix, A., Rodden, T., Davies, N., Trevor, J., Friday, A., & Palfreyman, K. (2000). Exploiting Space and Location as a Design Framework for Interactive Mobile Systems. *ACM Transactions on Computer-Human Interaction, 7(3),* 285–321.

Dyan, M. (2004). *An Introduction to Art, the Wireless Way*. Retrieved on March 25, 2005 from http://www.cooltown.com/cooltown/mpulse/1002-lasarsegall.asp.

Evans, J., & Sterry, P. (1999). Portable Computers and Interactive Multimedia: A New Paradigm for Interpreting Museum Collections. *Journal Archives and Museum Informatics, 13,* 113-126.

Feix, A., Göbel, S., & Zumack, R. (2004). DinoHunter: Platform for Mobile Edutainment Applications in Museums. In S. Göbel, U. Spierling, A. Hoffmann, I. Iurgel, O. Schneider, J. Dechau & A. Feix (Eds.), *Proceedings of the Second International Conference on Technologies for Interactive Digital Storytelling and Entertainment: Conference Proceedings - TIDSE 2004* (pp. 264-269). Berlin: Springer.

Fleck, M., Frid, M., Kindberg, T., Rajani, R., O'Brien-Strain, E., & Spasojevic, M. (2002). From Informing to Remembering: Deploying a Ubiquitous System in an Interactive Science Museum. *Pervasive Computing, 1(2),* 13-21.

Grinter, R. E., Aoki, P. M., Szymanski, M. H., Thornton, J. D., Woodruff, A., & Hurst, A. (2002). Revisiting the visit: understanding how technology can shape the museum visit. In *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work - CSCW 2002* (pp. 146-155). New York: ACM Press.

Hall, T., & Bannon, L. (2006). Designing ubiquitous computing to enhance children’s learning in museums. *Journal of Computer Assisted Learning*, *22*, 231 – 243.

Hayhoe, G. F. (2001). From desktop to palmtop: creating usable online documents for wireless and handheld devices. In *Proceedings of the IEEE International Conference on Professional Communication Conference – IPCC 2001* (pp. 1-11).

Klopfer, E., Perry, J., Squire, K., Jan, M., & Steinkuehler, C. (2005). Mystery at the museum: a collaborative game for museum education. In T. Koschmann, T. W. Chan & D. Suthers (Eds.), *Proceedings of the 2005 conference on Computer support for collaborative learning: the next 10 years!* (pp. 316-320). Mahwah, NJ: Lawrence Erlbaum.

Koshizuka, N., & Sakamura, K. (2000). The Tokyo University Museum. In *Kyoto International Conference on Digital Libraries: Research and Practice* (pp. 85-92).

Kuuti, K. (1995). Activity Theory as a potential framework for human-computer interaction research. In B. Nardi (Ed.), *Context and Consciousness: Activity Theory and Human Computer Interaction* (pp. 17-14). Cambridge: MIT Press.

Kwak, S.Y. (2004). *Designing a handheld interactive scavenger hunt game to enhance museum experience*. Unpublished diploma thesis, Michigan State University, Department of Telecommunication, Information Studies and Media.

Laurillau, Y., & Paternò, F. (2004). Supporting Museum Co-visits Using Mobile Devices. In S. Brewster & M. Dunlop (Eds), *6th International Symposium on Mobile Human-Computer Interaction - Mobile HCI 2004* (pp 451-455). Berlin: Springer.
Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation.* New York: Cambridge University Press.

Luchini, K., Quintana, C., Krajcik, J., Farah, C., Nandihalli, N., Reese, et al., (2002). Scaffolding in the small: designing educational supports for concept mapping on handheld computers. In *CHI 2002 Extended Abstracts on Human Factors in Computing Systems* (pp. 792-793). New York: ACM Press.

Luyten, K., & Coninx, K. (2004). ImogI: Take Control over a Context Aware Electronic Mobile Guide for Museums. *3rd Workshop on HCI in Mobile Guides*. Retrieved on February 24, 2007 from http://research.edm.luc.ac.be/~imogi/

Myers, B. A., Stiel, H., & Gargiulo, R. (1998). Collaboration using multiple PDAs connected to a PC. In *Proceedings of the ACM 1998 Conference on Computer Supported Cooperative Work - CSCW '98* (pp. 285-294). New York:ACM.

Mase, K., Sumi, Y., & Kadobayashi, R. (2000). The Weaved Reality: What Context-aware Interface Agents Bring About. In *Proceedings of the Fourth Asian Conference on Computer Vision - ACCV2000* (pp. 1120-1124).

Norman, D. A. (1986). Cognitive Engineering. In D.A. Norman & S.W. Draper (Eds.), *User Centered Systems Design* (pp. 31-61). Mahwah, NJ: Lawrence Erlbaum.

Norris, C., & Soloway, E. (2004). Envisioning the handheld-centric classroom. *Journal of Educational Computing Research, 30(4),* 281–294.

Oppermann, R., Specht, M., & Jaceniak, I. (1999). Hippie: A Nomadic Information System. In H. W. Gellersen (Ed.), *Proceedings of the First International Symposium Handheld and Ubiquitous Computing - HUC'99* (pp. 330 - 333). Berlin: Springer.

Patten, B., Arnedillo Sanchez, I., & Tangney, B. (2006). Designing collaborative, constructionist and contextual applications for handheld devices. *Computers and Education, 46*, 294 – 308.

Perry, D. (2003). *Handheld Computers (PDAs) in Schools*. BECTA ICT Research Report. Retrieved on February 26, 2007 from http://www.becta.org.uk/ page_documents/research/handhelds.pdf

Raptis, D., Tselios, N., & Avouris, N. (2005). Context-based design of mobile applications for museums: a survey of existing practices. In M. Tscheligi, R Bernhaupt & K. Mihalic (Eds.), *Proceedings of the 7th international Conference on Human Computer interaction with Mobile Devices & Services- Mobile HCI 2005* (pp. 153-160). New York: ACM Press.

Rieger, R., & Gay, G. (1997). Using mobile computing to enhance field study. In R.P. Hall, N. Miyake & N. Enyedy (Eds.), *Proceedings of Computer Support for Collaborative Learning – CSCL 1997*(pp. 215–223). Mahwah, NJ: Lawrence Erlbaum.

Rocchi, C., Stock, O., Zancanaro, M., Kruppa, M., & Krüger, A. (2004). The Museum Visit: Generating Seamless Personalized Presentations on Multiple Devices. In J. Vanderdonckt, N. J. Nunes & C. Rich (Eds.), *Proceedings of the Intelligent User Interfaces - IUI 2004* (pp. 316-318). New York: ACM.

Roschelle, J. (2003). Unlocking the learning value of wireless mobile devices, *Journal of Computer Assisted Learning, 19(3)*, 260-272.

Thom-Santelli, J., Toma, C., Boehner, K., & Gay, G. (2005). Beyond Just the Facts: Museum Detective Guides. In *Proceedings from the International Workshop on Re-Thinking Technology in Museums: Towards a New Understanding of People's Experience in Museums* (pp. 99-107). Retrieved on February 25, 2007 from http://www.idc.ul.ie/museumworkshop/programme.html

Vahey, P., & Crawford, V. (2002). *Palm Education Pioneers Program Final Evaluation Report*. Menlo Park, CA: SRI International.

Van Gool, L., Tuytelaars, T., & Pollefeys, M. (1999). Adventurous tourism for couch potatoes. (Invited). In F. Solina & A. Leonardis (Eds.), *Proceedings of the 8th International Conference on Computer Analysis of Images and Patterns – CAIP 1999* (pp. 98-107). Berlin: Springer.

Yatani, K., Sugimoto, M., & Kusunoki, F. (2004). Musex: A System for Supporting Children's Collaborative Learning in a Museum with PDAs. In J. Roschelle, T.W. Chan, Kinshuk & S. J. H. Yang (Eds.), *Proceedings of 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education – WMTE'04* (pp 109-113). Washington, DC: IEEE Computer Society.

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers and Education, 42*, 289-314.