Mystery in the Museum: Collaborative Learning Activities using Handheld Devices

Jorge Simarro Cabrera[1], Henar Muñoz Frutos[1], Adrian G. Stoica[2], Nikolaos Avouris[2], Yannis Dimitriadis[1], Georgios Fiotakis[2], Katerina Demeti Liveri[3]
[1]University of Valladolid, Spain, [2]University of Patras, Greece, [3]Museum of Solomos, Zakynthos, Greece
{JCabrera, HMFrutos, yannis}@yllera.tel.uva.es, { Stoica N.Avouris, Fiotakis }@ee.upatras.gr, museumsolomos@acn.gr

ABSTRACT
In this paper, we describe the experience of designing a collaborative learning activity for a traditional historical/cultural museum. The activity, based on a "Mystery in the Museum" story, involves collaboration of small groups of students through mobile handheld devices. An application has been built that permits authoring of such activities, while a usability evaluation study was performed that revealed some of the limitations of the design. The reported findings can be of use to those interested in following similar approaches in cultural and educational settings, and draw conclusions of general interest relating to interaction and collaboration through mobile technology.

Categories and Subject Descriptors
C.5.3 [**Computer System Implementation**]: Microcomputers – p*ortable devices (personal digital assistants)*.

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – c*ollaborative computing, computer-supported cooperative work,* s*ynchronous interaction.*

K.3.1 [**Computers and Education**]: Computer Uses in Education – c*ollaborative learning.*

General Terms
Human Factors, Experimentation, Design

Keywords
Collaborative learning, mobile technologies, museums, cultural information rich environments, PDA.

1. INTRODUCTION
This paper discusses our experience with designing and supporting collaborative learning activities in a Museum, using handheld devices. Mobile technology has made during the last years great advances in museums environments [5][6], so there are many reports of innovative systems involving mobile technology that have been used in various museums, first as electronic guides, subsequently as more powerful instruments for enhancing the visit and supporting rich interaction with the environments. New emerging technologies regarding mobile devices and their wireless network connectivity [7] have the potential to significantly enhance the experience of a visit to a museum, as visitors carrying wirelessly connected devices are provided with opportunities for exploration, requesting information, taking notes, investigating, communicating, evaluating and interrelating objects and concepts in the realm of the specific Museum. One particularly interesting use of such systems is related to educational activities [3] situated in the museums. These activities have been considered beneficial as they can be entertaining and stimulating for young children. In the reported here empirical study; we investigated a special kind of activity that involved collaboration of groups of children. Taking into account the importance of collaborative learning according to modern learning sciences [4][8] and the strong collaboration affordance of modern mobile technology, we designed collaborative learning activities for a traditional museum with a culturally and historically rich educational content. Then we developed a prototype that enabled and supported this activity and subsequently studied its use by typical students. The results of this study, reported here, include a discussion on the design process, including problems encountered, advantages and limitations of the technology used. These findings can be of use to those interested in following similar approaches in analogous cultural and educational settings, and draw conclusions of general interest relating to interaction with mobile technology.

The aim of the developed activity and the designed application prototype is to augment interaction with the museum through a mystery play that stimulates children's' imagination. The plot involves a number of puzzles that relate to the exhibits of the Museum and their solution brings rewards to the players. These puzzles, the most typical examples of which involve scrabbled images of certain exhibits and verses from manuscripts of the Museum, necessitate collaboration for their solution, as the necessary pieces are spread in the mobile devices of the members of the group. A negotiation phase is initiated then that results in exchange of items that can lead the group to a solution of the particular puzzle. The rewards have the form of clues that help the players solve the mystery. Since a large number of children (e.g. a school party) may be organized in multiple groups, the intention is to create competition among different groups. The aim of the activity is to mix the real and the virtual world and to make children work together in a collaborative way in this setting.

MobileHCI'05, September 19–22, 2005, Salzburg, Austria.

In the rest of the paper we discuss the design of the activities, we describe the experiment and evaluation of the system and finally outline conclusions we have drawn from both the development and the evaluation study.

2. DESIGN OF THE ACTIVITIES

The aim of the Mystery in the Museum (MiM) activity was to engage groups of students collaborating to solve a mystery inside the museum, interacting through mobile devices. The students thus need to be divided in different groups. Each group of students receives some information through the device and plays a role in the story. Thus, each group receives different pieces of information, so at the end of the visit they have to join and discuss together about the different clues they have collected, rebuilding the story and trying to solve the mystery. The typical age of the expected participants in the activity is 13 to 19.

Before the visit the teacher should review this topic with their students in order to deepen their background in the subject. Thus, the information they receive in the museum should be related with what they have learned, making them more interested in the visit.

When the students enter in each of the rooms they receive information that relates not only with the exhibits but also with the activity itself. Due to this, they collect enough information to help them find the solution of the mystery.

The activity aims at both making children learn about the specific topic and also at making them work in a collaborative way while learning. Due to this, each part of the activity involves collaboration of members of a specific group. In the developed puzzles, students have to work together in order to be able to solve them.

An activity preparation tool has been developed. This tool allows storing of predefined scenarios for activities and activation of them. Only one such scenario can be active at a time. The developed activities for the students visiting the museum include sequences of two puzzles – the *Text Game* and the *Image Game* - that have a common interface and they act as plug-ins for the mobile device front-end. This implementation decision allows for easy extension of the activities by adding more games with minimal changes necessary to the system in the future.

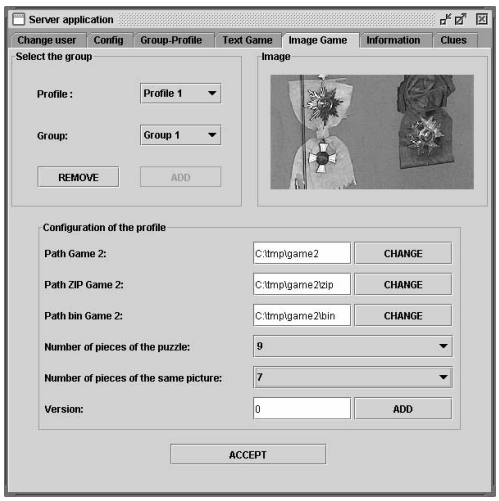

Figure 1 – The activity preparation tool for the puzzle game

The developed system provides thus a set of instruments to prepare the visit of the children in the museum that allow the museum staff in collaboration with the educators to prepare the visit activities the content that is delivered to the students as well as the way the content is presented. In figure 1 a snapshot of this environment is shown, in which a number of parameters are set for a puzzle involving an image (number of pieces of the puzzle, how the pieces are distributed among group members etc.)

There are also available post-visit aiding elements – the server produces a centralized log file (in XML) of the actions that take place during the visit and optionally this log file can be combined with a video recording of the visit allowing evaluation of the activity of the students during the visit. The format used in this logfile is that defined in the context of other collaborative environments like Synergo [2] and the Collaboration Analysis Tool (ColAT) [1]. This has permitted using ColAT in the analysis of collected data, as discussed in the following section.

Next we discuss specific characteristics of the two puzzles implemented: the text and image games: The TextGame‘s goal is to compose correctly a manuscript out of fragments of text. Each group member sees different verses of a poem in their PDAs. Afterwards the students should explore the room they are in order to find the manuscript that fits the verses they have received. So, they should attempt first to put in order the sentences they have received. The problem is that they only receive a subset of the verses. So they have to exchange them with the other group members in order to form correctly the poem. Once they receive all the needed verses, they have to place them in order in order to complete successfully the particular game.

In the ImageGame each student has to solve a puzzle. Each one receives a set of image pieces that belong to different images, split into pieces and shuffled (see fig.2). Due to this, they will have to exchange the pieces between them in order to have all the parts of the chosen image, a necessary step for solving the puzzle correctly. When the users receive the pieces of the puzzle they should look for the item they think it could be the solution of its puzzle. The fact of seeing the solution of the puzzle – that for example can be found in the physical environment like a painting, a picture, statue etc –supports them in solving the puzzle.

3. EVALUATION STUDY

The developed prototype was evaluated by a controlled experiment in a setting that resamples a typical context of use of the system (A Historical/Cultural Museum). A school party of children in their first year of senior high-school (aged 15 to 16, the expected typical user age) participated in the study. The party was made of twelve (12) children (3 boys and 9 girls) divided in three groups of 2 teams having two members each that were randomly formed. Two of these groups were made only of girls and one group was composed of 3 boys and one girl.

The scenario involved puzzles and scrabbled verses related to a well known poet and the rewards were in the form of clues that when put together revealed an important date of the history of the region. Each game has been played by every team once. In the case that one member successfully finished the game, the corresponding clue was obtained.

The games played by the teams followed two predefined profiles. All teams of the same profile had identical initial state for their games. The children that participated in the experiment were supported by the tutors and the evaluators with information about the exhibits of the museum and received instructions on the rules of the games. They had the opportunity as well to ask at any time for help from their tutors and evaluators.

The teams gathered the clues and then each group debated and discovered collaboratively what the combined clues were in order to solve the problem.

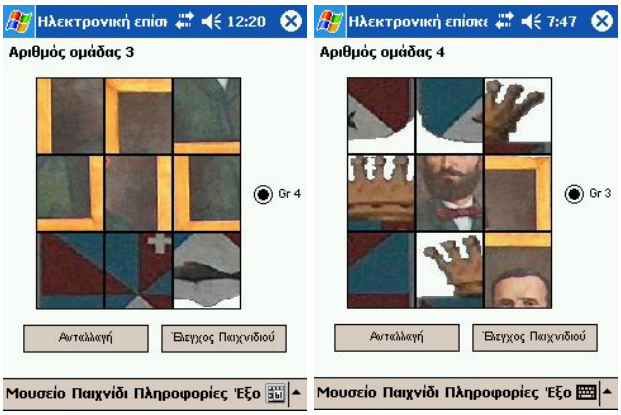

Figure 2 – The ImageGame. Side by side the screenshots of two members of one group

The experiment was recorded by 3 video and 2 audio recorders for further analysis using ColAT which interrelates activity logs video and observers notes in the same environment. So the actions on the PDAs, that were logged by the server, where synchronized with the videos. During the experiment at least one evaluator observed the behavior of the children. The observers also played the role of the museum guides and they explained to the participants how to use the application and what is the goal to follow in playing the games.

Several observations have been made: In all teams for all games the log had a common pattern that shows that the participants were engaged first in exploring at first the interface of the games. After the period of exploration they start the real game play to achieve the desired goal. The interface is very intuitive considering that none of the participants have used before a handheld, though all of them have mobile phones (so they are used to mobile, small display constrained devices) and over 30% of them have a PC at home.

Observers have noted that the teams that identified the exhibits in the Museum walls and used them as reference completed the games in a much shorter time. Overall it was observed that the PDAs drew most of the attention, as the participants at most used the surroundings just as a means to solve the games and to get the reward in the form of the clue.

The TextGame generally took much longer to complete than the ImageGame as there were no fragments of the text in the physical space, though the poems chosen were well known to the children. As opposed to the ImageGame the TextGame involves some scrolling in order to place the verses in the right spots and it does not support an overview of the text. The children that have not succeeded to solve the text puzzle expressed their wish to have the solution presented in the game – feature that is not present. This feature is not present in the ImageGame either, however the fact that the images can be found in the environment fulfills this requirement. Also the increased time required to do the TextGame could be related to the fact that higher cognitive load is required, as the users need to remember the sequence of the verses that was even harder due to the necessary splitting of the poem in short phrases. The optimal strategy for the ImageGame needed only three (3) exchanges in order to have both players win status. The optimal strategy for the TextGame was different for different profiles (4 phrases for profile2 and 6 phrases for profile 1).

Table 1. Performance for ImageGame

G*	P**	Member	ImageGame				
			Time	Events	Exchanges		Completed
1	1	PDA 1	6'35"	101	9	3	Yes
		PDA 2	6'18"			6	Yes
	2	PDA 3	3'05"	47	3	0	Yes
		PDA 4	3'31"			3	Yes
2	1	PDA 1	4'22"	46 ~	3	2	Yes
		PDA 2	6'26"			1	Yes
	2	PDA 3	2'49"	41	5	4	Yes
		PDA 4	2'56"			1	Yes
3	1	PDA 1	2'29"	47	4	3	Yes
		PDA 2	3'32"			1	Yes
	2	PDA 3	4'59"	71	7	4	Yes
		PDA 4	4'14"			3	Yes
Average:			4'16"	~59			
Average by profile:		1	4'57"	~65	~5		
		2	3'36"	53	5		

* Group, ** Profile

The results presented in Tables 1 and 2 show us that there is a significant difference between profiles 1 and 2 especially for the TextGame. We can notice a very big difference in the average times by profile required to play the TextGame (profile 1 with 11'07" compared with profile 2 with 3'25") as well as in terms of successful completion of the game (profile 1 33,33 % compared to profile 2 with 100%).

Table 2. Performance for TextGame

G*	P**	Member	TextGame				
			Time	Events	Sentences sent		Completed
1	1	PDA 1	16'15"	76	6	2	Yes
		PDA 2	14'19"			4	No
	2	PDA 3	03'15"	24	4	2	Yes
		PDA 4	03'17"			2	Yes
2	1	PDA 1	12'27"	57	11	4	No
		PDA 2	11'32"			7	No
	2	PDA 3	03'46"	41	6 ***	3	Yes
		PDA 4	03'29"			3	Yes
3	1	PDA 1	06'08"	29	4	0	Yes
		PDA 2	05'59"			4	No
	2	PDA 3	03'24"	31	4	2	Yes
		PDA 4	03'20"			2	Yes
Average:			7'16"	43			
Average by profile:		1	11'07"	54	7		
		2	03'25"	32	~5		

* Group, ** Profile , *** 5 successful + 1 unsuccessful sentences sent

The explanation for these results lies in the differences in the contents of the two profiles, as profile 1 dealt with more text than 2. Also the poem of profile 2 is well known, as it is the first verse of the Greek National Anthem. The larger poem also resulted in noticeable differences in the interaction. As already mentioned the children were familiar with small screen devices but they were not used with the stylus. From the observations that were made during the experiment turned out that in the TextGame they had difficulties to scroll the text with the stylus and often they tented

to miss a phrase when they moved from one scroll page to another. The lesser quantity of text in profile 2 allowed the players to overcome easier these problems while the text in profile 1 made the game harder for them. Some times during the game children felt frustrated and often remarks like "I can not stand it any more!" or "This is impossible!" were heard.

Also we can note that since the verses in the task for profile 1 were less recognizable by the participants they had even more difficulties in completing the puzzle. So none of these teams had the patience to complete in both PDAs the text. In the teams that finished the game they stopped immediately after one of the team members got the corresponding clue. Opposite to this behavior was that of profile 2 where all participants wanted to complete the task on their PDA.

Profile 2 results are very interesting with regard to the time needed for solving the ImageGame and the TextGame. The average time for the TextGame is lower than the average time for the image game, an observation against our intuition. The explanation is that the users got accustomed to the devices during the ImageGame, that was in all teams the first game they have chosen to play. So they had already learned the basic elements of interaction and they got the idea of the games. Repeating the ImageGame resulted in reduced completion times as expected. This behavior is clear in the profile 1 where the times required to complete the TextGame where high compared the times required to complete the ImageGame for just 2 extra lines of additional text, as the increase of required time seems to be exponentially related to text quantity.

Comparing the average time required by profile 1 for ImageGame with the one required by profile 2 we can see a slight difference that is explained through the fact that the images in profile 2 contained slightly more edges and shapes that eased the completion of the game.

The strategies that the teams adopted for solving the games differed from team to team. The most common was to stick together and sometimes move around to find the relevant picture on the walls of the museum. One exception was in the 3rd group 1st team who have exchanged the pieces of the desired image to form and then they split, each partner moving close to the relevant exhibit in order to finalize the puzzle. For the TextGame, profile 1 players only tried to find information in the physical environment that could help them to complete the task with the verses. It is of interest to note that there were teams that adopted an optimal strategy in terms of exchanges. In spite of the fact that other teams had less than optimal strategies the times for completion were close. Collaboration between team members was in various forms: the collaboration patterns expected and provided by the system – exchange pieces of images or text sentences through the game interface; verbal collaboration; helping the team mate to find the relevant information in the physical space as well as some times selecting on PDA the desired piece of information.

4. CONCLUSIONS

Design and evaluation of the Museum system has been a hard task. Despite the many technical difficulties related to the selected development environment, the application entered a beta testing phase after six months of development and recently the prototype went into the evaluation phase that involves a series of usability evaluation studies like the one described in section 3.

Some of the findings concern the activity characteristics: A possible drawback of the proposed activity is related to the fact that we may be building a tour oriented to the PDA instead of the museum, so that it could be possible that visitors interact more with the handheld devices than with the exhibits. In our evaluation study, the visitors indeed used the exhibits rather as auxiliary material towards the main objective, i.e. solving the given problem, however the conditions where simulated and the emphasis of the particular study was clearly on examining interaction during the activity. An additional concern, as discussed in the evaluation section, is related to the fact that it is possible that the games are too difficult for children of the target age group. If children find the games difficult to play they will lose interest in them. However the developed authoring environment has the capability of adjusting the level of difficulty in various ways, so thorough testing of future activities with children of the target age group should be done before introducing the activity in a museum.

Overall the activity is not invasive of the environment, as no visible intervention is required in a museum, while the scenario can be adjusted for many different Museums.

Finally the developed prototype is expected to be used for studying various aspects of group interaction through mobile devices in the near future and validate the developed usability evaluation methodology, especially since it is combined with logging mechanism and powerful analysis tools like the ColAT environment.

5. REFERENCES

[1] Avouris N., Komis V., Margaritis M., Fiotakis G., *An environment for studying collaborative learning activities*, J. of Int. Forum of Educational Technology & Society , , 7 (2), pp. 34-41, April 2004 .

[2] Avouris N., Margaritis M., and Komis V., (2004), *Modelling interaction during small-group synchronous problem-solving activities: The Synergo approach*, 2nd Int. Workshop on Designing Computational Models of Collaborative Learning Interaction, ITS2004, Maceio, September 2004

[3] Davis, S. M., *Research to Industry. Four Years of Observations in Classrooms Using a Network of Handheld Devices*, WMTE'02, 2002

[4] Dillenbourg P. (ed.) *Collaborative-learning: Cognitive and Computational Approaches*. Advances in Learning and Instruction series, Pergamon, Elsevier, 1999

[5] Exploratorium, *Electronic Guidebook Forum Report*, San Francisco, October 11-12, 2000

[6] Hsi, S., *The Electronic Guidebook: A Study of User Experiences using Mobile Web Content in a Museum Setting*, WMTE'02, 2002

[7] Roschelle, J., *Unlocking the learning value of wireless mobile devices*, Journal Computer Assisted Learning, vol. pp. 260-272, 2003.

[8] Roschelle, J. and Pea, R., *A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning*, Int. J. of Cognition and Technology, vol. 2002