Mobile Collaboration Tools and Systems to Support Ubiquitous Learning

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Abstract

Current developments in mobile, wireless and positioning technologies combined with contextual computing are contributing to the advance of new mobile applications and services. Educational environments are being subject to these changes providing an opportunity for curriculum development that can use these socially based mobile devices for supporting different aspects of learning and teaching. But these new technologies raise crucial questions about what features and capabilities collaborative mobile tools and systems should provide to support different learning activities. In this paper we present our current work related to the development of a system that use web and mobile technologies to support collaborative and ubiquitous learning. We also illustrate three specific collaborative learning scenarios supported by our tools. The results of our activities provide us with valuable insights that can help us to identify future challenges related to the design and implementation of this kind of collaborative systems.

1. Introduction

Current developments in mobile, wireless and positioning technologies combined with contextual computing are contributing to the advance of new mobile applications and services. The rapid adoption of sophisticated mobile devices and applications has created new social tools for people to connect and interact; therefore changing the ways we communicate and collaborate. Mobility offers new dimensions to support and promote meaningful learning activities that include features such as connectivity, social interactivity and context sensitivity [4]. From this perspective, mobile technologies provide ways to enhance the learners' context by the creation of embedded ubiquitous environments in authentic settings. This provides innovative ways of interaction with novel forms of collaboration.

During the last four years we have been conducting research efforts that explore new design approaches and innovative uses of wireless and mobile technologies in a variety of collaborative educational settings. Our vision is not simply to provide novel mobile and wireless computational tools, but rather to explore new and varied educational activities that become available while applying innovative approaches for designing new technology to support learning. Technical innovation in these areas is particularly characterized by using new types of interaction devices and new communication technologies such as mobile computers, smartphones, GPS enabled devices, visual codes, physical interfaces with smart interactive objects and wireless networks in ubiquitous computing environments. Our envisaged and partial already existing research results are software components and architectures that facilitate personal and group communication in a wide range of collaborative learning activities. Therefore, in the context of our efforts one main research question can be formulated as follows: *Which technological features and capabilities are required to support collaborative mobile learning across different locations?*

The paper is structured as follows; in section two we present the theoretical foundations that have guided our work, while in section three we briefly present the project and the trials we conducted. In section four we discuss the conceptual design of the system and tools we have developed. In section five we describe three specific scenarios that illustrate collaborative learning activities supported by our tools. Section six presents the conclusions together with future directions of our work.

2. Theoretical Foundations

Computer supported collaborative learning (CSCL) is the label of a well-established community of researchers with a multidisciplinary background, including computer science, cognitive science, education as well as sociology and social psychology. Learning is seen as a social process in which meaning, information and knowledge are negotiated between learners through collaboration [3]. In collaborative settings, learners discuss, argue and engage in shared activities in order to create understanding and representations of knowledge. Within this broad framework of CSCL, our specific design orientation focuses on scenarios using mobile and ubiquitous technologies. Mobile computing devices allow for exploratory activities not bound to a special location, for example field trips, without losing the potential of taking electronic notes and retrieving information of various types. Such notes, ranging from data collections and digital images to handwritten annotations, can be easily exchanged and downloaded. If combined with wireless transmission and location information, these activities can be continuously monitored and coordinated between places. But even in classrooms and training settings with more or less fixed locations, the use of mobile and wireless technologies may lead to substantial changes in that small hand-held or embedded devices are no longer dominating the interaction in the same way as an "explicit" computer does. This can help us to bring the technology to the background and to set the focus more on collaborative inter-personal relations and on the task at hand. The design of technological support for collaboration and communication in ubiquitous learning environments is a difficult process, not only because the learners may be separated by time and space, but also because they may not sharing the same learning location. Establishing common ground and mutual understanding; two important ingredients for collaborative work and learning, [1,2] become a challenge.

3. The AMULETS Project

The ongoing AMULETS (Advanced Mobile and Ubiquitous Learning Environments for Teachers and Students) project explores how to design, implement and evaluate innovative educational scenarios combining outdoors and indoors activities supported by mobile and ubiquitous computing. AMULETS is based on the premise that the design of innovative mobile learning activities should be guided by collaborative learning scenarios in context in authentic settings. Since June 2006 we have conducted five different trials using educational scenarios that were designed together with teachers to support the regular curriculum in a wide range of topics including geography, history and biology. In this paper we present only three of these cases, which are described in more details in section 5. The first case is the Växjö Square trial conducted in the fall of 2006 with twenty-nine 5th grade students (11-12 years old). This trial had co-located groups of students working together from the field and a museum to learn about the local history of the town square throughout the centuries. Figure 1 images (a) and (b) show an example of collaborative learning tasks. The second case took place in the spring of 2007 with 16 university students from our teaching training program. The learning activity in this case was on how to learn about tree morphology where the field students used a tree key to identify different species of trees by bark, type of buds, and the surrounding environment. The main tasks were to locate and identify the trees, take pictures and send these images back to indoor group and collaboratively determine the tree species. Figure 1, images (c) and (d) illustrate these tasks. The third case took place in the fall of 2007 with eleven students enrolled in an elective mobile game course conducted in a local school. The goal of this weekly class was to work with the students to design and to develop a mobile educational game that was played by other students. This new game was based on the Skattjakt game platform (Treasure Hunt) that was implemented to promote physical activity and collaborative problem solving by the unique combination of orienteering and mobile technology [9]. In figure 1, images (e) and (f) illustrate a task and the physical aspects of the treasure hunt. In the coming section we will describe the conceptual ideas and technologies we used in our implementation.

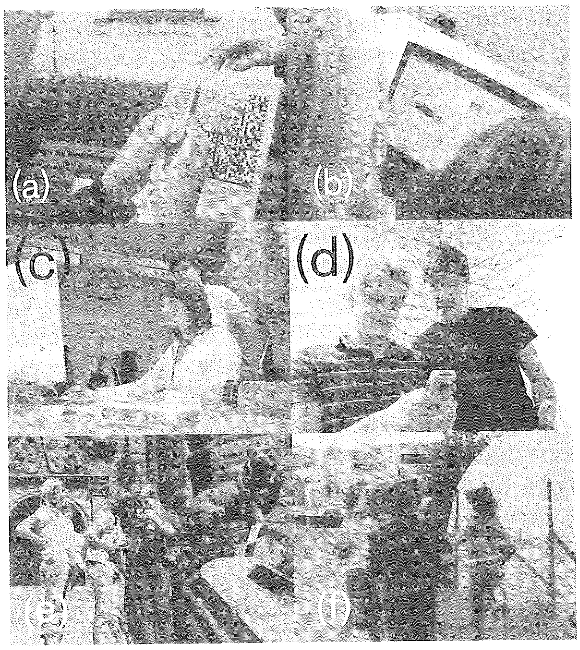

Figure 1 The AMULETS project in action

4. Conceptual Design and Development

This section contains an overview of the mobile tools and systems that supported our work surrounding the implementation of ubiquitous learning activities. In order to support the different collaborative learning activities we have developed and implemented a number of mobile tools and applications. In the technical architecture presented in figure 2, we illustrate the three main components of the technical system. The central component is the Learning Activity System (LAS) that is comprised of three main functional blocks, the Activity Generator, the Collaboration Tools, and the Presentation Engine. In the next sub sections we will examine the different components that make up the Learning Activity System.

4.1 The Activity Generator

One of the core components of the LAS is the Activity Generator (ACS). The Activity Generator contains the Activity Control System (ACS) that enables collaboration between users and devices while retrieving and storing the content. It also controls the flow of the learning activities. In its core, ACS serves as a task manager where user-generated content and metadata can be incorporated to influence the task flow and outcome of learning activities. The ACS was designed around a conceptual framework developed by Kurti and colleagues [5] to support contextual metadata. Whenever instructed to save the state of an ongoing learning activity, the system stores a snapshot of the conceptual framework instance. Each snapshot describes the activity state at a certain point in time and place, and may include references to user-generated content, such as chat messages, photographs, or movie clips. The ACS runs in an open source environment (Linux, Apache, MySQL, PHP) and the main method for clients' interaction rely on HTTP requests.

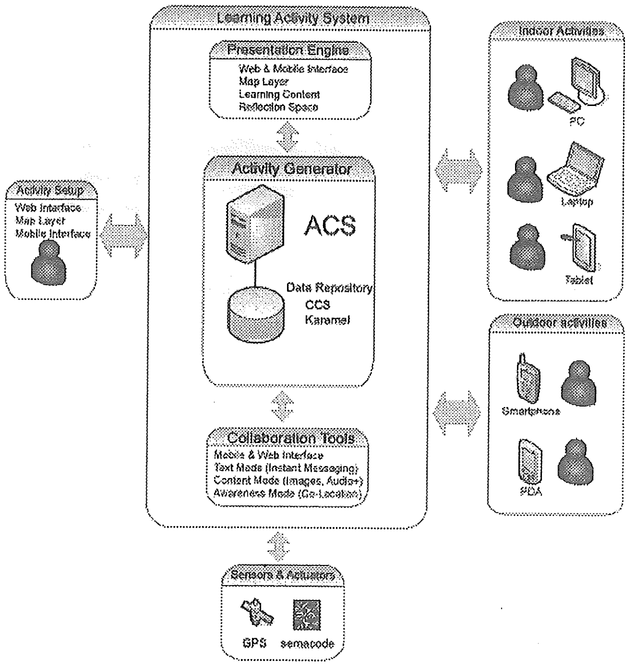

Figure 2 The Learning Activity System (LAS)

4.1.2 The Data Repository

The data repository provides different methods to store and retrieve context aware content from the LAS. The first method is using the CCS (Collect, Convert and Send) system. The CCS is able to extract metadata from the different file types sent to it, even if the file type is originally unknown. File analysis tools we developed were used to provide the extraction process with the necessary metadata information. Beyond the LAS context, CCS provides also a number of tools for doing media conversion, such as text-to-speech. Built as a service oriented architecture, CCS uses mainly web services for communication. The Karamel system (see ACS diagram in figure 2) provides a more lightweight repository that focuses on ease of data retrieval, depositing of data and application interoperability. In Karamel, content is stored as entries in topics. As a topic can be related to another topic, this provides some sort of granularity when categorizing content to be stored in our repository. Additionally, entries can be tagged and this feature can be used for filtering a set of entries based on a certain criteria.

4.2. Collaboration Tools

The Collaboration Tools provide the literal bridge between groups outside and inside through instant messaging, images, and audio. For the outdoor activities, as those described in section 3, we have used smartphones and PDAs with GPS capabilities to interact, create, collect, and communicate throughout the learning activities. These devices exchange data with the LAS components retrieving and sending content and information, as well as they interact with the sensors. The Collaboration Tools enable the technology-mediated support for remote groups to work together by providing text, content, and awareness modes.

One of the components in the collaboration tools package is a series of mobile clients that rapidly provide content to the LAS coming from the participants in the activities. The first version of this tool was able to instantly take pictures with the click of a button and send them to the content repository where they were stored together with the appropriate metadata. In the current version we have added audio recording capabilities and support for GPS devices. The tools contribute with contextual and environmental metadata when storing user-generated content in the LAS repositories.

The collaboration tools running on mobile devices consist of applications developed using technologies such as Flash Lite, Python for S60 (PyS60) and Nokia Web Server. Some of the collaboration tools that exist in the LAS run in limited environments, thus a RESTful approach to data storage and retrieval was used allowing HTTP enabled applications to communicate with the repository without using protocols such as SOAP.

4.3. Presentation Engine

If ACS can be seen as the controller of a learning activity, the Presentation Engine (PE) is a toolset used to visualize events surrounding this activity. Traditionally, the process of outdoors documentation is carried out by using different devices like digital cameras, dictaphones or simply plain pen and paper. These activities may generate a huge amount of distributed data that needs to be manually gathered, cataloged and at some point interpreted. We also see that using the devices previously mentioned leads to a loss of important data, such as the exact time an object was photographed. Ambiguity is also an issue due to human factor issues when recording a location. There is also a risk to lose the data completely if the responsible party forgets to document it. The PE uses middleware and client-side scripting to present and visualize content and metadata from the data repositories. Examples of technology used by the components of the PE include Google Maps API, SOAP, RDF and KML.

4.4. The Activity Setup & the Sensors and Actuators

In order to facilitate the creation of learning activities, an activity setup interface was designed in which administrators can add, modify and create a logical structure to the educational flow of a learning task. In more detail, the activity setup is a graphical web interface that allows adding, grouping and hierarchically structuring actors and tasks. It is also used for sequencing tasks to create a main educational flow within the learning activities. Some clients in the collaboration tools package are equipped with semacode readers (2D visual codes, see www.semacode.org). These are used to provide easy triggering of events that would occur in activities controlled by ACS. The GPS module used by LAS collaboration tools is the Nokia LD-3W. The smartphones connect to the GPS via Bluetooth and parses NMEA sentences that are sent from the module.

5. Educational Scenarios

In this section we describe a specific task for each one of the three scenarios mentioned earlier in section 3. These tasks illustrate a collaborative situation designed to create a common ground and to promote mutual understanding. Each of the three different trials had roughly six tasks that each of the groups needed to collaborate in a peer-to-peer mode. Moreover, the first two trials supported collaborative tasks across locations.

5.1. Växjö Square

In the Växjö Square trial, the students traveled back through the centuries exploring the history of the town square. For the example presented we will examine the case from the 19th century where the students needed to find the location of a building that used to stand on the south side of the square. The students in the museum had access to an old photograph and live streaming web cam from the square. The students in the field were able to take photographs with the smarphone that were automatically sent to the indoor group and appeared in the browser next to the antique image. The two groups had to negotiate a solution to this task using text messages and the images sent back by the field. The indoor group was able to direct the outdoor group to the location via the use of semacodes. The outdoor group could choose the correct location or be "scaffolded" to the correct choice via animated help guides available in the smartphones.

This trial was the first learning activity in which the ACS system was used as the activity controller. When the activity rules and task flow were formalized onto paper, the ACS activity setup interface was used to generate the activity on a dedicated server. Devices establishing communication with the ACS consisted of a laptop as well as several mobile phones, used by the indoor group and outdoor group respectively. The outdoor group triggered tasks by scanning semacodes with the activity mobile phone, which then updated the ACS by sending URL parameters. The change of state in ACS would then be visible for the indoor users. The ACS then updated the indoor groups web page and delivered 3GP movies to the smartphones in the field. The content phone ran a collaboration tool, which sent photographs to ACS using HTTP POST. The communication phone ran as an instance of the Nokia Web Server, which bundled a tool for making messages sent to the server appear as pop-ups in the phone's interface.

5.2. Teacher Students

In this trial, we worked with 16 teacher students enrolled in an environmental science and biology course. We expanded the collaboration mode to include audio comments as the means of communication between the indoor and outdoor groups. The field students were required to document different aspects of specific trees. Sending back audio comments and images to a web interface and at the same time the indoor group used this information to help identify the tree species. Semacodes and the use of animated guides provided educational support for both groups. This provided us with the opportunity to use audio as a means of communication for the students in the field.

Structurally, the teacher student trial shared several similarities with Växjö square trial. The ACS was used as the activity controller, and each group consisted of an indoor group, stationed with a computer running an AJAX-powered web application, and an outdoor group equipped with several Nokia 6630s. The main challenge in this trial was that all participating groups should perform the activity simultaneously. Furthermore, the number of mobile phones used by the outdoor group was reduced to two: one activity phone and one content phone. For this trial, the functionality of the Python application running on the content phone was extended to support audio recording. The student controlling the content phone could, with a single click on the asterisk key, switch between camera and audio mode. When a photograph or audio recording was created, the file, as in the previous trial, was automatically sent to the ACS system and instantly visible, or listenable, to the indoor groups web application. Since this trial didn't have a communication phone as such, it relied on other ways to communicate between the groups. From the outdoor group to the indoor group it was a simple matter. Since the outdoor group had the ability to take photos and even record sounds that could instantly be seen by the indoor group, the outdoor group had no trouble getting their messages through. The other way around however, proved to be a bit more challenging and relied for example on providing comments to the outdoor group when they provided an answer for a task. Some tasks even relied on the indoor group having to answer to a question correctly in order to give hints to the team outdo

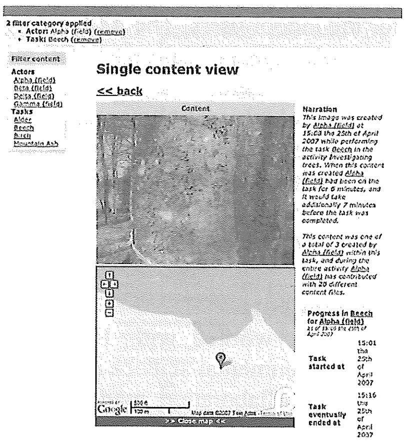

Figure 3. The RDF browser

For this trial, ACS features were enhanced to generate RDF documents representing different stages of the learning activities. The RDF data was then used as input data for a content browser web application. Within this web application, user-generated content could be sorted out and filtered based on their role in the learning activity in which they were created. A filter criterion could, for instance, be specified as "all content created by the second group during the third task". These features are illustrated in figure 3.

5.3. Skattjakt

For this trial, in addition to the game experience on the mobile phone (a Flash lite application), we introduced photographic tasks for each one of the groups using a second phone paired with a GPS sensor. As the game experience progressed at each of the locations, the group was assigned a photographic task to be completed. As each group took photographs, these were automatically uploaded with geo-tags to our repositories and visualized on a Google map. The latter was done in real time, thus allowing teachers and researchers to follow up the different groups. During the post-activity workshop the students and the research team gathered and reflected over the game and the photographs using the visualization tools.

The communication between the Flash Lite application and the ACS was implemented by using the HTTP connectivity features of Adobe Flash. When the phone sent a request to ACS, it returned XML that is parsed by the client. The Flash application was designed in a way that the International Mobile Equipment Identity (IMEI) for each phone is included in the request sent to the ACS server, as well as the unique ID activity number that can be identified by the ACS. Based on the values of these variables, the ACS will respond accordingly and proceed with the activity.

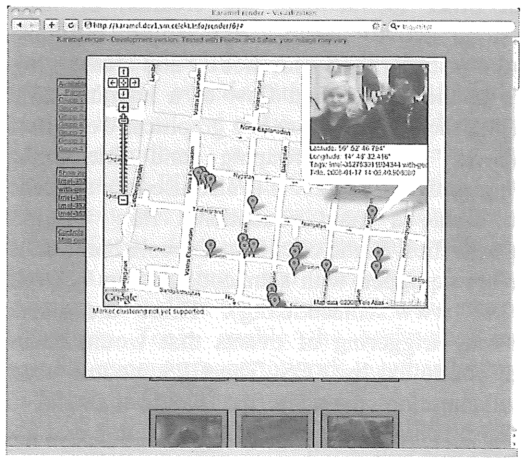

Figure 4. The post activity collaborative reflection space

A Nokia N70 paired with a bluetooth-enabled GPS device was used to take the pictures. We developed a mobile client using Python for S60 that connects to the GPS, providing location data to be stored with images in the repository. Additionally, images were tagged with IMEI to further support filtering. During the post activity the students, teachers, and researchers went over the game using components from the Presentation Engine to collaboratively discuss the results. Figure 4 shows an example of filtering the images collected during the game by group and location using the geo tags.

6. Discussion and Future Efforts

In these three different scenarios, we implemented challenging learning situations by augmenting physical spaces with information exchanges as well as using geospatial mappings between the mobile devices and the real world that facilitated navigation and collaboration. We have explored these different collaboration modes between groups of students at across locations supported by our tools. We have taken this approach to investigate which technological features and capabilities are required to support different collaborative learning activities. In the Växjö Square, the students had to collaborative in real time using photographs and text to locate where a building stood 100 years ago. For the teacher students case, audio and photographs were exchanged in order to create an augmented field experience and for them collaborative share in learning how to identify different trees. In the Treasure Hunt, we created a reflection space by utilizing the photographs mapped in real time to locations enabling the students' use the tools to discuss the game and photographic tasks. What is key to the future success of ubiquitous technologies and mobile collaboration tools in the classroom is to see how the added numerous benefits to the teaching/learning process does not hinder the natural flow of learning [7]. Chan and colleagues [6] use the term "seamless learning" to describe these new situations. Our results also indicated that collaborative learning activities enhanced by ubiquitous technologies should not be regarded as stand alone activities, as they should be part of a thoroughly developed educational flow that also is combined with traditional ways of teaching and learning. Spikol et al., [8, 9] provide an elaboration of these results and further details about impact on the learning activities.

Mobile and ubiquitous technologies offer the potential for a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different learning contexts. From a technical perspective we have used a software component approach to build a number of applications related to data portability, media migration and reusability of information in educational contexts. Several tools were developed and implemented using a wide range of technological solutions in order to illustrate the potential benefits of re-using media, visualizing content in context and merging "the wired" Internet with the "wireless" world.

In our future work we will explore how to add new features to the LAS system such as location triggered collaboration tools, as well as to expand the range of sensors to help make data from the field tangible in the learning process. Another issue that deserves further investigation is how to develop robust concepts and methods for integrating contextual information as part of the metadata to be stored in our learning object repository. More specifically, we are exploring in which way standards such as IEEE LOM and IMS-LD can be combined with web-based ontologies. The pre-determined metadata slots defined in the mentioned above standards needs, in our opinion, to be extended to support the necessary contextual and environmental characteristics, such as group progress in activities, custom metadata tags and user-generated content.

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