Research and Practice in Technology Enhanced Learning
Vol. 4, No. 1 (2009) 83–107

MOTEL: A MOBILE LEARNING FRAMEWORK FOR GEO-TAGGING AND EXPLORATIONS OF SITES FOR LEARNING

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Mobile networked digital devices are near ubiquitous, owned by just anyone, in many parts of the world today. Together with positioning techniques this opens for new innovative educational practices through the design of location aware systems. After studying a technology rich university-level discipline, a mobile learning framework, MOTEL, that supports geo-tagging and publishing of tagged areas overlaid on digital maps was designed and implemented. By following an iterative design process it has been possible to answer questions about how it is possible to use locative media to support learning for explorations of sites for learning. The findings from this research and development consist of a set of challenges that need to be solved in current and future mobile learning environment designs. This paper describes the design process that has lead to the MOTEL framework, the framework versions, including a test scenario, envisioned and planned use cases, and the challenges that need to be solved for future designs.

Keywords: Mobile learning; design; GPS; mobile application framework.

1. Introduction

During the last decade, mobile digital technologies have become an important and integral part of our lives through the personal use of advanced digital devices. Digital tools are presently, ubiquitous, whether it is for learning, work, communication, recreation, or entertainment. Mobile phones, digital personal assistants, portable media players,[1] digital entertainment gadgets, and game consoles[2] are all devices that blend transparently into our lives. For the youth of today, they are hardly thought of as technologies anymore —- they are just a "mobile" or a "game station". As youth are becoming more accustomed to using a plethora of devices, they are

[1]For example, more than half of all Norwegians own a portable digital audio player and the number is rising. Source http://www.ssb.no/emner/07/02/30/medie
[2]In Norway 61% of all boys and 32% of the girls (9–15 years old) are playing games each day. Source http://www.ssb.no/emner/07/02/30/medie

also using more complex functions such as mobile chatting or posting edited images to online sharing communities. One question is if it is possible to take advantage of these tools and emerging digital skills in educational settings or learning activities in general.

The aim of the research and development reported in this paper is how mobile technologies can enhance and support learning activities in both formal and informal settings. While earlier ways of thinking about mobile learning were to deliver content and tasks to smaller and more limited devices in order to support "anywhere–anyplace" modes of learning, the focus here is slightly different. First, the focus is on developing tools and mechanisms in such a way that learners can go from being consumers to active producers, of content in collaboration, as participants of meaning making, and, second, to create tools and mechanisms that enable people to be critical consumers and re-mixers of ready made content (Lessig, 2004).

The perspective guiding the work reported in this paper is a design perspective where knowledge and explorations about the world is gained through building and testing informed designs using iterative design cycles. In this way, I am actively involving myself in shaping the future, a tradition that corresponds to a Scandinavian informatics perspective (Dahlbom, 1996). This includes gaining knowledge about current practices (e.g. through employing ethnographic flavored field studies), making informed designs and re-designs together with stakeholders and users, conducting real world participatory tests, and theorizing about the tools and practices involved.

This paper begins with a look at selected examples of related mobile learning research. Then my initial field studies, where I followed a technology rich discipline at university level in order to gain insight into their practices and their future needs as a basis for a mobile learning system design, are described. Next, I present the first design cycle of a mobile learning framework, named MOTEL (Mobile Technology Enhanced Learning), and the main results from the user tests conducted, which feed requirements and ideas into the next design cycle. Then the second version of the framework is presented and a description of how it is being used in various learning activities including how we envisage it being used in other future learning activities is given (from learning about local cultural heritage to making a mixed reality learning game). The paper concludes with a discussion about what mobile learning means in the context of this work together with some design challenges.

2. Enhancing Learning Using Mobile Devices

One of the first to promote ideas of using portable and personal computers as a tool for learning was Allen Kay (1972). Kay provided the public of the time with a vision about a portable computing device for learning, named the DynaBook, to use for learning (or "portable information manipulator" as he chose to call these devices). Kay did not claim that computers were *necessary* for children in order to learn, but rather that computers can provide children and adults alike with a better and more flexible tool. He also argued that the pedagogical merits of a personal computing device was undeniable — this is an idea and vision supported even more today, for example through the One Laptop per Child project initiative (see http://laptop.org).

In recent years, there has been an increasingly focus on enhancing learning by means of mobile digital devices. This field is often referred to as *mlearning* (short for "mobile learning"), and today it is a versatile and broad research field where several different approaches are taken. Technologically, the focus has been on how portable devices such as ultra-portables, tablets, PDA's, portable game consoles and mobile phones can both support existing learning activities and offer a way to innovate and create new learning practices. Fixed devices such as large shared information displays and other infrastructure that connect the mobile learner to other resources can also be included in mobile learning systems. Further, mobile learning can be seen to be orchestrated, as in a classroom setting, or serendipitous, such as walking into a geo-fenced area in an outside museum, and the type and role of technology typically varies with context of use (e.g. primary schools, higher education, museums, professional development and training, life-long-learning etc.).

While there are some that believe that mlearning's main task is to make sure opportunities for learning (with an emphasis on content and tasks) is accessible for students independent of time and place, anywhere – anytime learning, others go beyond this initial idea and focus on how mobile learning is about learning across contexts, with and without technology engagement, and how people engage in learning in both formal and informal settings (see e.g. Sharples, Taylor & Vavoula, 2007). Yet others focus on how mobile devices afford learning through integration of activities that occur in multiple spaces, context enrichment through, for example, location awareness, and identification as mobile devices are often the learner's personal device (Dillenbourg, Jermann, Weinberger, Stegman & Fischer, 2004). This section describes selected examples where mobile technologies are being used to support learning activities.

2.1. *Participatory simulations*

One innovative category of utilizing mobile technologies in education is through participatory simulations where small handheld devices are used to "lay" out an augmented reality simulation in a group of students. Studies such as Colella (1998) have shown that participatory simulations motivated participants to take part in the simulation and learn about the subject matter, enabled better shared task solving, provided a rich base for collaboratively designing and running experiments, and led to a new language to talk about the mechanisms to be learned in the simulation play. In another project Wilensky & Stroup (1999) focused on employing participatory simulations as a way of fostering the understanding of dynamic systems (a field they see as a new kind of literacy and thus mobile devices as an important technology to gain competences in this emerging field). Last, it is also interesting to see that many of these researchers try to utilize and create game play in their settings in order to engage and motivate their students to participate in the learning activities (e.g. Klopfer, Squire & Jenkins, 2002).

2.2. *Science education*

Another area of use of mobile technology in education is the use of probes and sensors in science education. These projects often use probes attached to mobile devices in order to investigate real, often immediate, natural phenomenon such as temperature, light, and acidity (Bannasch & Tinker, 2002). Others are designing specific field trips, and complete ambient areas, where probes are used together with a supporting infrastructure constituting complete intelligent environments (for example, see Ambient Wood, Rogers *et al.*, 2004; Rogers & Price, 2008). The advantage with regard to these collaborate settings is that the small form factor of these devices supports social interaction more easily, and the increased computing performance enables data from the probes to be processed on the spot and scrutinized in collaboration in a way not possible before. This provides the learners with new representations, such as powerful visualizations, suitable for learning about a topic under study while *in situ*. In this way, school classes can bring tools, and complete activities that were traditionally only available in the lab into the field, making the learning experience both richer and more real.

2.3. *As mini-computers*

In other projects mlearning is looked upon mostly as an extension of elearning where mobile devices are viewed as supporting "anytime and anywhere learning". Research is focused on how existing learning objects, learning content, and exercises can be adapted to fit on small devices with limited resources (see e.g. Rekkedal *et al.*, 2005). Furthermore, there are efforts to make industry standards for mobile learning that enable this. This is an approach where one tries to overcome the limitations of mobile computing devices as compared to desktop computers with regard to size of display, processing power, battery, and connectivity (see e.g. The MILE project at http://www.mile-project.net). In addition there is a commercial market and a growing interest from elearning companies in producing both content and applications that are adapted to fit on small devices. For example, Avantgo is a commercial service that delivers special formatted content to small screen devices, and Adobe has made a version of Flash (Flash Lite) that is popular for making mobile learning packages for mobile phones. Another example is the porting of desktop learning applications to mobile devices. The Inspiration mind-mapping tool[3] is such an example. Math4Mobile[4] is another similar example where the idea

[3]See http://www.inspiration.com/productinfo/handhelds/index.cfm
[4]See http://www.math4mobile.com/

is to provide a student with the opportunity to do math when traveling with the bus to school.

2.4. *Guides*

Another active area of research and development is the use of mobile devices as digital guides for use in museums (also exploratoriums) by tourists or visitors walking around an area or part of a city (Abowd *et al.*, 1996). The promise lies in using mobile technology to enhance the experience for the visitor by extending the visit with before and after visit activities. By adding a learning dimension to the guide, it becomes a tool for both exploration and reflection. Research questions are often asked about how these technologies affect the engagement of the visitors with the various exhibits, and how they coordinate and navigate between the augmented virtual exhibit and the real exhibit (see e.g. Spasojevic & Kindberg, 2001).

2.5. *Coordinated classroom activities*

There is also an area of research where researchers have been orchestrating, in detail, collaborative activities through the use of mobile devices. In these instances, mobile devices are usually seen to be better suited for facilitating collaborative learning by supporting the close social interaction necessary to coordinate collaborative learning tasks (e.g. Zurita & Nussbaum, 2004). For many of these projects, detailed analysis of the interaction afforded by small devices has resulted in the design of applications and activities that take advantage of the affordances of using small mobile devices in collaborate face-to-face interactions. Last, the use of individual feedback mechanisms such as classroom response systems have been seen as one simple and affordable, but successful, mobile technology use in several US classrooms (see e.g. Roschelle, 2003).

2.6. *Location aware systems*

An area increasingly receiving attention is the utilization of positioning technology as an element in mobile learning systems. Simultaneous to the huge improvements in small mobile computing devices, there has been progress and important developments in positioning technology that has laid the foundations for using this technology as a part of mlearning activities. One important event happened in 2000, when restrictions on availability of GPS were lifted by the US Clinton administration. This meant that everyone, not only the US Department of Defense, would have access to much more accurate positioning data for free. One popular early use of GPS was the adoption of geo-caching in science and math learning, or the variant eco-caching where the emphasis is on exploring natural or cultural spots in the field. In eco-caching the spot itself is the cache (e.g. a particular botanical species in the field). Other projects are focusing on using location technology to automatically input location data and create contextual adaptive applications and data for field workers (e.g. Pascoe, Ryan & Morse, 2000). One larger research effort is the GIPSY project (now continued as the Manolo project) (Wentzel, van Lammeren, Molendijk, de Bruin & Wagtendonk, 2005), which uses a commercial GIS application adapted for use on small mobile devices. Using handhelds and GPS technology the students can use the GIS application to navigate to real sites of interest for a particular study topic. The Collage project (Spikol & Milrad, 2008) is another project where GPS is being used to create mlearning gaming scenarios. However, GPS is not the only location technology one can use. The widespread use of 802.11 wireless LAN networks has lead to several projects that take advantage of this in making innovative new applications. For example, the CatchBob! application (Nova & Girardin, 2004) uses 802.11 location technology in their application as a means for students to navigate and coordinate joint efforts in a game.

2.7. *Summary*

This is not an exhaustive list of mobile learning, but rather diverse examples of some of the current approaches to using mobile devices in learning. Some of these are examples of novel learning experiences afforded by the mobility, computing, and networking capabilities offered by these devices. We see that new technological innovations give new opportunities for pedagogical innovation. The remainder of the paper addresses the MOTEL application, starting in the next section with a description of the design oriented research approach taken.

3. Design Oriented Research

In the tradition of Scandinavian design research (see for example Ehn, 1993), I take a multi-disciplinary approach to interaction design that is based on a public dialog with active participation of end-users and is focused on people, societal values, ICT functionality, and aesthetics. As Bannon and Bødker (1991) explain, design is "a process in which we determine and create the conditions which turn an object into an artifact of use. The future use situation is the origin for design, and we design with this in mind … To design with the future use activity in mind also means to start out from the present praxis of the future users (p. 242)". This means that there is a tight connection between design and use and that when we design, we are designing for a future practice (Wasson 1998), informed by the present. Thus, the current practice of learners as they move between their learning venues, is studied with an eye on designing a mobile learning technology to support their learning activity as they move between these venues (i.e., identifying the role(s) for mobile technology). This is similar to a study carried out by Wasson (ibid.) where she studied a net-based simulation used by on-campus students in order to inform the design of a future collaborative tele-learning environment where this same net-based simulation game would be central.

Next I describe the empirical studies that formed the foundation for the first design of MOTEL. Using the results of these studies, a number of informed design decisions that were made are described followed by a detailed description the first version of the MOTEL framework.

4. Empirical Studies

In order to get insight into how biology students and faculty were using technology in their day-to-day activities I carried out ethnographically flavored field studies (Hughes, King, Rodden & Andersen, 1994), group interviews, and, last, organized several workshops with a selected group of students. The ethnographic work was centered around a team of marine biologists and I chose to follow them on one of their field trips (as this was an interesting aspect of being a biologist from the standpoint of a mobile learning designer and researcher). For this group of marine biologists that meant going out on a boat cruise to gather and scrutinize samples of marine life for use in their teaching and research activities (this particular group studied various mollusks). The aim of these observations was to get an understanding of what field work meant for this particular team of marine biologists. This involved observing what tools were being used, what tasks were performed, including the interaction and communication that took place between the participants.

In a later stage interviews were conduced with staff and students (in this group interview a professor researching bark beetles participated in addition to the original marine biologists). They were asked about: the kind of tools (both analog and digital) they used in their learning activities (to gather, organize and present information, to communicate); the kind of digital tools they owned and used in other lifetime activities; and where they used those tools (e.g. at home, the reading room, or at sea). The interview questions were motivated by our belief in the importance of leveraging existing digital tools, learners habits and resources (such as instant messaging tools, mobile phones, weblogs, wikipedia, etc.) in order to take advantage of them in supporting future learning and research activities. Interestingly, the students and professors themselves did not think many of these were resources for learning, just tools for everyday life.

In addition to these interviews two workshops were organized with two biology master students (one for each of them). Both of them had a master thesis theme that required them to do field work in the woods. One of them had to study (and count) ticks on deer for a long period of time inside a particular geographic area on the west coast of Norway. These workshops started with an exercise where we collaboratively mapped out *what* tools, resources and learning activities was used and performed *where* in relations to their master thesis work (similar in theme to the questions asked in the group interviews reported above). In this workshop we focused specifically on their master thesis work rather than on the generic role of being a biology student as it is important in design workshops to create a setting where the student can make "active contributions that are meaningful to themselves" (Bødker, Ehn, Sjogren & Sundblad, 2000, p. 7). They were asked what worked well in the current situation, what did not work that well, and, last, what

Figure 1. A team of marine biologists using an encyclopedia as a resource in discussions.

they felt was missing. Focusing on their specific tasks that had to be accomplished in their field work was in that sense a wise one as we could focus on specific future technology support and solutions for the highly mobile part of their thesis work.

From these investigations, the following characteristics of use were identified:

(1) Reflecting the mobile society in which we live, both students and researchers frequently change their site of learning including the classroom, home, reading room, wet labs, at sea, on board boats, in the woods. For this they are in need of a supporting infrastructure that can facilitate what they bring across these various sites.
(2) Various uses of maps are very important for this discipline. In particular, we identified that most data are attached to a specific location or geographical area (geo-referenced), most frequently in the form of a coordinate, and that this location is pivotal for the research field. Further, maps are used as a tool and shared resource in social interactions, for illustrating findings and data in papers and reports, and in analyzing data both in the field and back at the office, using for example Geographic Information Systems (GIS). Figure 2 shows an example of map usage; the biologists used this digital map on a monitor on board a boat as a resource when discussing findings and planning where to go next.
(3) Researchers and students alike are interested in mechanisms to support sharing of data, for example, when students work together in projects, or sharing in broader online communities. There are some national and international initiatives to make online databases for sharing material and collections (for example, species databases) but they were hardly used (this might change in the future).

Figure 2. Map usage by biologists on an excursion.

(4) Biology is a very technology intensive field and most tools are becoming digital. This is one kind of "convergence" where their tools such as cameras (video and still), and all sorts of measuring equipment are now equipped with a digital interface enabling easier computational manipulations.

The results of the empirical studies of the biology students and faculty gave great insight into a technology rich learning discipline at university level. These characteristics of use, however, are relevant for several other disciplines at university level and elsewhere (e.g. for life long learners). In particular maps and locations are getting increasing attention and are increasing in importance. Data gathered, objects of study, including findings and analysis, are often related to a location or delimited area in a whole range of disciplines in addition to biology. For example, in the study of Norwegian language dialects, the location where a dialect originates or is found today is important, or in archeology where artifacts are found is extremely important. Similarly, the use of maps is also an important tool and resource for disciplines such as system dynamics, geography, meteorology, and history.

The conclusion that a geo-tagging system can be used in several disciplines (and even for life-long-learning purposes) led to a decision that a generic mobile learning framework, and not one for biology in particular, should be designed and implemented (even though we built some table support specific for biology data gathering). Another foundational idea used as a guideline in the development was that I wanted a system where the user is the main creator and initiator of information and communication, or that the learner at least can shift among the roles of learner, designer, and active contributor (Rogoff, Matsuov & White, 1998). This is in contrast to a more traditional mass communication mode model where central content creators makes (or "broadcasts") content to consumers as many new and existing technologies are unfortunately designed to treat humans only as consumers (Fischer, 2003). We thus subscribe to Fischer (ibid) that "the fundamental challenge for computational media is to contribute to the invention and design of cultures in which humans can express themselves and engage in personally meaningful activities".

The result of the design is the MOTEL (Mobile Technology Enhanced Learning) framework described in the next section.

5. The MOTEL Framework

While building support for mobile learning can encompass a whole range of issues, the first design iteration of MOTEL focused on developing support for 3 aspects: (1) geo-tagging used for messaging and data gathering (and for later retrieval using proximity techniques); (2) interoperability between various devices (by using platform independent protocols like XML-RPC, and open source development platforms like Java ME[5]); and (3) easy re-use, publishing, and editing of data (including conversion mechanisms between formats).

The first version of the framework focused on virtual tagging of locations. This framework (see Figure 3) currently comprises an application for mobile telephones (an open source Java ME application), the use of GPS for positioning, and a server back end for receiving, storing and easy publishing of the notes. The application enables easy user creation of notes and tables, both of which have attached

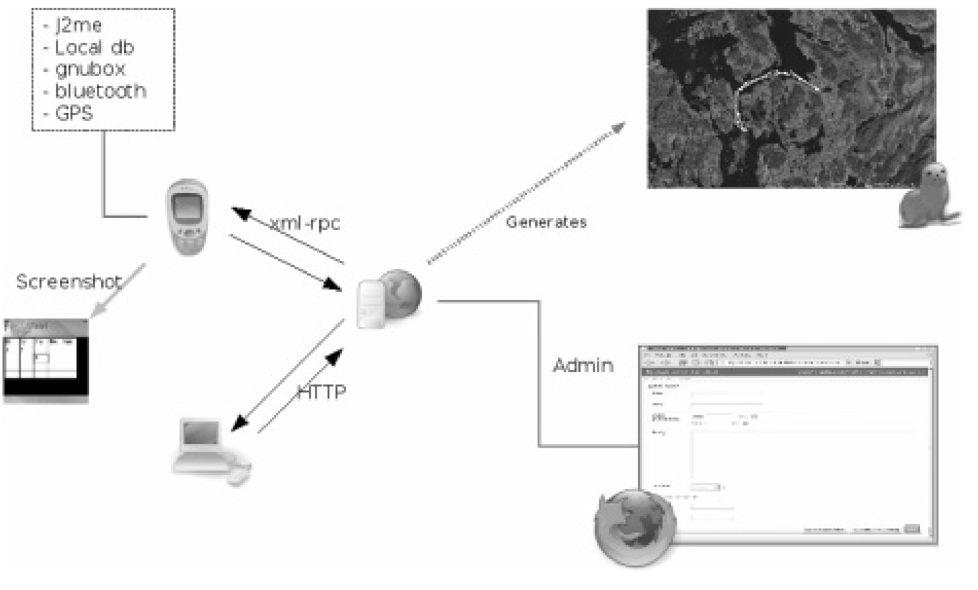

Figure 3. The MOTEL framework.

[5]http://java.sun.com/javame

coordinates as latitude and longitude. The notes can be stored locally on the phone, edited on the phone, or be sent to a central server database for later retrieval when being in the field. In addition there are server side scripts for automatic publishing of the notes overlaid on maps and for publishing in the Atom[6] XML format (this enable RSS readers to subscribe to a group of learners notes).

5.1. *Target device*

The mobile phone was the target device for the prototype and is also the main device platform for future development. The main reasons for focusing on mobile phones were: (1) all age 13–34 Norwegians own a mobile phone (Ling, 2006), with SMSing being very popular; (2) mobile phones are truly portable. Laptops are also portable, but are best used on a flat surfaces and the WIMP (Windows Icons Menus Pointers) interaction paradigm normally demands full attention and is unsuitable in a "using while moving" setting (Pascoe, Ryan & Morse, 2000); (3) costs — PDA's were also considered, but they are more expensive than most mobile phones and are not in widespread use in Norway; (4) mobile phones are always on, or on standby, and carried by their owners; and, (5) we believe mobile phones have an underused potential as a tool for learning and see this as a design challenge given the other advantages mentioned above.

5.2. *Target development platform*

The Java Micro Edition (Java ME) platform was chosen as the development platform for the mobile phone client application because we had previous experience with this platform, but more importantly it is both a widespread and portable technology. Other advantages include its potential for further development through Open Java Community Processes. Java ME has also recently become Open Source Software so it fits with our philosophy of not supporting a particular proprietary system. The Python programming platform[7] was also considered since we all had Nokia S60 phones that supported Python, but although Nokia is the most sold mobile phone brand in Norway (and the most sold smartphone model in the world) we wanted to support as many brands of mobile phones as possible, and found that with Java ME platform we could do so more easily.

5.3. *Positioning*

One of the challenges was how to enable positioning in order to attach location metadata to a note or a table. We considered using the following positioning techniques:

(5) Cell towers: Java ME has a location API that can use information from cell towers in order to approximate the position of the terminal, but this is not

[6] http://www.atomenabled.org
[7] http://opensource.nokia.com/projects/pythonfors60/index.html

supported in Norway. Norwegian tele-operators use their own methods for positioning using cell towers and subscription web services, and it is expensive and not accurate enough for our use (typically the accuracy is within 500 meters in urban areas and up to 10 km in rural areas). There are, however, some promising initiatives, like Place Lab (see http://placelab.org) and CellSpotting (see http://cellspotting.com), but when my project started they were not an option.

(6) Wireless base stations (802.11): it is also possible to use 802.11 wireless base stations in an area in combination with techniques that do proximity sensing to position a mobile terminal as long as it has a wireless adapter. This method can only be used in areas with wlan base stations, and require calibration and that each mobile phones has a wlan adapter/card. This method was not an option because we wanted user scenarios where the user was in locations such as at sea and in the woods where there are few or no wlan stations. This, however, is a great option for indoor positioning (e.g. see the CatchBob! Project).

(7) GPS positioning: GPS is the most used positioning technology and is being used by airplanes, space shuttles, boats, ships and cars. Although its accuracy varies depending on place and device being used, it is considered accurate enough for many applications (in our tests varying between 3 and 15 meters in urban areas), and is very reliable. Is also covers the whole earth, but needs free sight of the sky — while good at sea, it could be a problem in a highly dense forest, and in some area in cities with high buildings.

(8) Bluetooth base stations: This is an option for controlled scenarios (e.g. inside a museum) when short range is sufficient. As a positioning technique it is similar to 802.11 wireless base stations, as they both will utilize some form of proximity sensing to locate a user.

(9) Visual codes: Embedding location data in visual codes (e.g. QR codes) is another option. This, however, requires the placement of a visual code sticker at a particular location beforehand, and is again only suited for controlled scenarios. Further, one needs a camera phone to shoot a photo of the code that the application translates into a URL with embedded positioning data. Thus, this is neither automatic nor a quick operation for the user.

We decided to use GPS as location mechanism and external GPS devices with bluetooth connection to each users mobile phone. The decision to use external GPS receivers was due to Bergen being cloudy and mountainous and tests of many integrated GPS devices revealed them to be poor compared to external ones (in accuracy and time to get fix). Second, mobile Phones with internal GPS devices also use a lot of battery, and third, few students owned a mobile phone with integrated GPS, but most were in possession of a phone with a bluetooth adapter. Last, we wanted the users to be able to move freely around in areas without the calibrated and ready-made installations that are necessary in order to use any of the other positioning techniques.

5.4. *Local storage support*

Supporting local storage on the mobile phone was a feature we needed to support for several reasons. First, when working with educational institutions it is important that costs are kept to a minimum and the user does not feel restricted with respect to annotating locations. With a local database functionality the user has the option of deciding later which notes and tables to upload. Second, it is possible to use a desktop computer with an existing Internet connections to connect to the server to submit notes. In MOTEL we used Gnubox, a Symbian software application that lets you use a bluetooth connection to connect to the Internet using a computer, to facilitate this further.[8]

6. MOTEL: Second Development Cycle

Our development and testing of first generation MOTEL gave us further insight and ideas about how new innovative learning activities can be designed. The testers and the development team brought up several interesting issues (see Section 8). One was that even though we had a focus on students themselves generating data there was a need, especially by teachers, to build and take advantage of the concept of geofencing (proximity sensing) and pre-defined virtual hot spots that could trigger user actions based on proximity.

This was also influenced by our collaboration with the local City Inspector of the Inspectorate of Ancient Monuments and Historic Buildings.[9] In this collaboration we are making part of the city's cultural heritage digital accessible for visitors and its inhabitants. This is an encompassing project that contains issues of many kinds that needs to be solved (e.g. digitalization of historic validated information). One part of the project is the development and deployment of a mlearning component. The idea is to develop location based services based on MOTEL for the facilitation of exploration of a particular rich cultural heritage area of Bergen (this area is called "Sandviken"). One concern from their side was that they wanted a model of validated notes and hotspots (in terms of origin of the information) as well as generic user generated notes as a way to get user feedback and involvement. This corresponded with the wish from the teachers after testing the first version and this was then supported in the new version.

Geofences are virtual fences that trigger actions or guide the user when entering or leaving a specified area. Virtual hot spots are similar to placemarks or "points of interests" (POI) where a more narrow location is triggering some action on the user device. This set of new features were to become the focus on the next version of MOTEL, and the idea was to enable instructors (or some other authority) or

[8]The normal way is to use the mobile phone via bluetooth to access the Internet using e.g. a laptop. This is the other way around.
[9]The municipal official who manages the cultural heritage in the city.

peer students to make pre-defined learning routes for each other in addition to the functionality of leaving virtual notes at a location.

With the next version of MOTEL an area can be divided into squares, virtual hotspot areas, that each trigger an action on the user mobile phone when entering or leaving the square. Virtual hotspots can be defined with an action radius that triggers the delivery of pre-defined multimedia objects to the user mobile phone. For each hotspot, it is possible to define an combination of an audio, text or graphics file (see Figure 4), that will be presented to the user when entering the radius set to trigger a virtual hot spot (an extra hint in the form of calling the telephone's vibrate function will let the user know that she has entered the radius of a hotspot). The media objects can be delivered from a central media database over-the-air, or from a pre-loaded media database located on each user's extension memory card. For this use case a user will have to start the discovery modus in the application before entering an area with predefined hotspots. This area is labeled a *site for learning* in the MOTEL vocabulary.

Another change in our development was that we now developed for mobile phones with internal GPS units in addition to phones using external units. Our tests now showed an accuracy of 3–8 meters with these phones and we believe that internal GPS units will be "the next killer application" for mobile phones (predictions are that more than half the mobile phones sold within the next 5 years will be equipped with an internal GPS unit according to Fjord Consulting (2007). Nokia alone envisages selling more than 35 million GPS enabled phones in 2008 only).

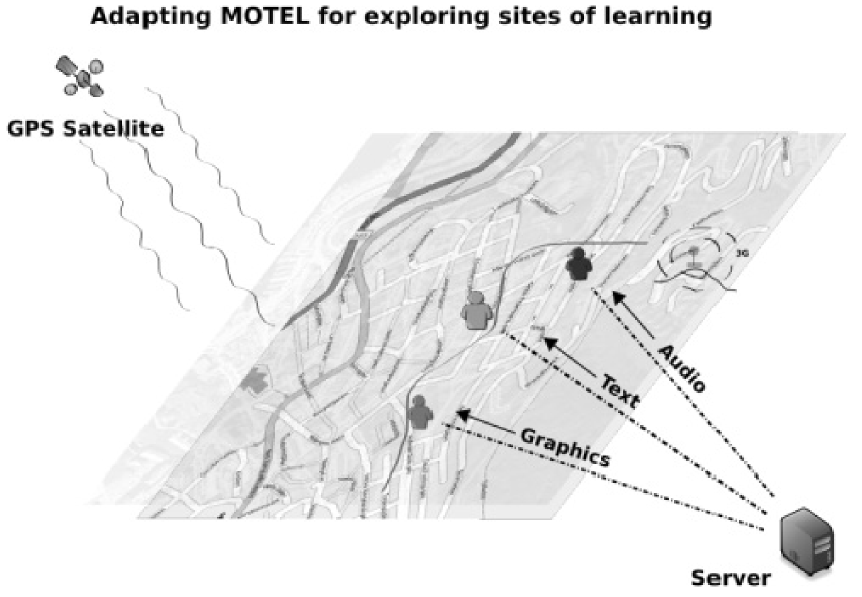

Figure 4. MOTEL with added functionality for adding virtual hot spots.

More than ever MOTEL leverages existing publishing standards and web services available with open API's. For example, all notes are published in ATOM/RSS format. This enables interested parties to follow whenever a new hotpost or virtual annotation is added to the database with their favorite aggregator/RSS reader. The hotspot database is also converted to formats readable by GPS devices such as Garmin, in addition to publishing the raw data in KML (Keyhole Markup Language) that enable the hotspots to be viewed in Google Earh and other KML reader applications. First, this is related to how we want to support the crossmedia phenomenon and open data[10] models of education, by offering students the possibility to use various media in learning and communication. This involves making it possible to post multimedia to the system and to make services for clients and devices other than J2ME enabled mobile phones. This we believe is an important issue to be aware of when developing educational applications for the future, when the range of digital devices owned by students will vary more than ever. Second, this is a way to open up and publish much of the material for self-paced learners and for the general public.

Last, we have made a simple way for each user to rate the hotspots they discover. This is a mechanism for fostering a critical use of the application and a way to enable feedback in the system. This idea is, among others, modeled after user driven news sites (such as http://www.reddit.com and http://www.digg.com) where each user nominates and votes on what should be the day's news to be displayed on the front page. This is also a way to enable user participation in our system as it can be used to generate user top 10 lists of hotspots rather than just the routes and hotspots nominations made and decided by a central authority (e.g. the municipal) or instructors leading a course.

The next section describes concrete uses of MOTEL in learning scenarios for students in Bergen.

7. Sites for Learning

MOTEL is seen as part of a socio-technical infrastructure and an emerging framework for generic virtual annotations and for explorations of sites for learning. Seeing it as part of a socio-technical infrastructure means that we simultaneously develop learning activities using the system and that the system must be seen as part of those activities and not as a separate entity.

7.1. *Local history*

To explain the functionality of MOTEL, we sketch one of the designed user trails where a group of students are learning about local history while exploring Bergen and making notes about historic buildings they encounter (this is similar to the task

[10] See http://en.wikipedia.org/wiki/Open_data

we had students carry out during the usability testing of the MOTEL application). The students are divided into groups order to cover the city.

Preparation: Each student downloads the Java ME MOTEL client application over the air or by getting it beamed over bluetooth (or infrared). An administrator makes user accounts on a MOTEL server (the client application can be used stand alone but then there is no uploading of notes). The user has a GPS device in her pocket. Then the client application needs to be configured for use with the server and the GPS device; a configuration tool will automatically locate any GPS device close by and present a list from which she picks the GPS device. The student is now ready to begin the exploration of the city.

Virtual Annotating: Whenever the student encounters a historic site she wants to annotate with a note or a table, she clicks on add a note (or table) in the client on her mobile and writes a title for the note and then a short text (see Figure 5). When pressing "save" she will be given the option to save the note with location coordinates attached — and a virtual annotation has been created.

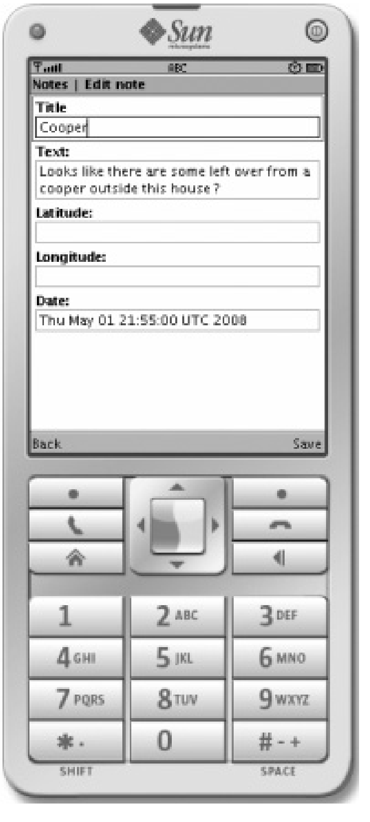

Figure 5. Screenshot of the GUI form for writing and adding an annotation.

Managing the Notes: Later the student can select from a list the notes she wants uploaded to the server (needs server authentication). Since the notes (and tables) are saved locally they can be edited and deleted on the mobile if needed before posting them to the server and when cleaning up old notes. It is also possible to wait until she is back at her office and use Gnubox, a bluetooth adapter and her desktop computer to send the notes to the central server database.

Retrieving Notes: One interesting feature of the client is the built in note retrieval mechanism. There are two ways to receive notes (both will send a call to the server). First a request for all notes written by a particular group ID (e.g. retrieve all notes written by my group) can be sent to the server. Second, it is possible to retrieve all notes within a radius of X meters (contains very advanced calculations due to how the earth is curved). This, for example, enables the group of students to retrieve other notes by their group that have been posted at the same spot, or near to a spot, or to check if any virtual notes already exist for location she is considering annotating.

Route Tracking: There is also a route tracking mechanism in the application. If the student wants to track the route she is moving along she can start a point logger. The point logger is meant to be used in evaluating a route after a learning scenario or as a mechanism in multi player games adopted for learning. The point logger, however, cannot be used without continuous network access, as it needs to post coordinates in real time.

Publishing Notes: On the server side, a relational database with an interface written in Python and an experimental administrator interface built with the Django framework is being tested. A set of server side scripts generates views of the notes and tables as maps with overlaid notes and tables as clickable points (see Figure 6). A script, using the Google Maps API, retrieves their data from a relational database (posted by the mobile phone client). The user can also log on to this administrator interface using a web browser to get access to her notes and tables where she can edit, delete and even add new notes.

7.2. *Cultural heritage*

To test the second generation MOTEL, where we added geofencing and hotspot features, we developed a learning scenario for exploring cultural heritage sites in Bergen. In this learning scenario we worked together with the City Inspector of the Inspectorate of Ancient Monuments and Historic Buildings and the local municipal to identify and collect information about cultural heritage sites, and objects, for a delimited area of the city Bergen.

Ten hotspots were added to the system and each hotspot denoted 10 different cultural heritage objects in the area of Sandviken, Bergen. The objects were diverse and were all illustrated by an image and a text explaining the history of the object. Some selected objects were given an additional audio file. The objects, or spots,

Figure 6. Shows an example map view of generated notes.

identified a whole range of cultural heritage instances, from a specific house representing a typical old profession (e.g. a cooper), or an area denoting an old market or square. The learners that participated in the tests were asked to go through an area with the application put in discovery mode. When the user approached one of the hotspots the phone would vibrate, and then an old historic photograph of that particular cultural heritage object would be displayed for the user. The user could then decide to just take a look at the image or read more about that particular hotspot object (if interested in the topic or part of a mandatory assignment), or move on to the next hotspot.

There are also hotspots that trigger the playing of an audio file and the idea here is that it is important for the user to keep focus on the real object denoted by the virtual hotspots and not on the mobile screen alone. With audio this can be accomplished and the audio can guide the user to focus and look at the real object (e.g. a particular old style window). In this way the system enhances the experience of the location and give added value information to the learner in the form of tailor made explanations in audio format. Additionally, audio is a means to meet increasing requirements of universal design.

In addition, the note function from the first version of the MOTEL Java ME client was added as a way for users to ask questions about a particular location to other users of the application, or about an arbitrary other location the user found interesting.

In the next section the findings from these user tests are presented and a discussion about how I see these findings as continuous design challenges for mobile learning is undertaken.

Figure 7. Example of an image displayed to a user approaching a cultural heritage object.

8. Findings

Developing mobile applications it not an easy endeavor. Mobile phones are diverse with regard to properties such as screen size and resolution to more subtle characteristics such as where hard buttons are located on a phone (Greenhalgh *et al.*, 2007). To deal with this diversity we decided to define a baseline phone around which we centered our design (with regard to capabilities such as CPU power, memory, screen size and resolution etc.).

On the use side it is not easy to develop new and novel learning activities. There are few guidelines to follow in developing mobile learning activities, compared to the plethora of guides that exists for developing for the stationary computer. In a situation like this, it is even more important to follow an iterative design methodology.

The framework has been tested in various ways during development. I have conducted rapid users tests during development for testing micro user interface elements designs such as user dialogs and screen flows (ensuring screen flows are smooth and enabled by one hand operations). These tests have given feedback regarding aspects of the interface from what kind of icons to use in menus to how a particular task could be accomplished using a particular screen flow design.

On a higher level we have designed small-scale field trials with students where they have been given particular tasks to accomplish in order to test specific design options. For example, one trivial but important aspect of the application was how to lead the user through the GPS setup. This was tested several times before I settled on one of many design options.

Last, I organized a "design crit" (modeled after design crits used in architectural education) where I presented the framework, the origin of the various implementation decisions, the background to the application, and also what problems I've been struggling with to a group of master students in a CSCW (Computer Supported Cooperative Work) course. Part of this session included a user test where the students tested the application walking the streets of Bergen using both the virtual tagging feature and the hotspot discovery mode. This use was observed though following several of the groups around during the trial. This test ended with a discussion where the students asked questions and commented on their experience of using it. In this session several issues pertinent to mobile interaction design and learning were brought up. The rest of this section will report these issues.

First, the students welcomed an application for mobile phones; an application that should be used on a mobile phone is natural for most of them. Even giving them some of the test mobiles (of a different brand than the one they themselves owned) was not a problem. This indicates how today's youth are more accustomed to and are skilled users of mobile technologies. When we tested our first prototype 3 years ago this was not the case. At that time a mobile application scared some of them and some showed a reluctance to use their phone for tasks other than calling and sending messages. During my time with the students in the CSCW course they expressed no fear, or reluctance, to the application, and they even enjoyed playing around with it. This can be related to how mobile phones (or just mobiles as they are being called now) are being increasingly used for more than voice calls. Calling someone is today, in many cases, secondary to other services such as using SMS, using the camera, and online services.

8.1. *Transforming spaces into learning places*

From a theoretical perspective we see that by adding virtual tags to an area has the potential to turn seemingly empty areas (digital knowledge wise) into rich and meaningful "places" for mobile learning. This can be related to one of the main concerns in ubiquitous computing (see for example Hightower, 2003) of how to turn locations/positions into "places", where places are what is valuable for humans while locations are only coordinates in a system. Places are the semantics that are imbued with human connotations, making it into a useful source for human living. Hightower (ibid) mentions labeling positions by grassroot movements as one option for turning positions into places. I see MOTEL as one effort in that direction, but as a means to tag complete areas into learning places and rich sites for learning.

8.2. *Mixing the real and the virtual*

It is possible to divide mobile applications into a continuum where at one end you are developing an application that is independent of place (and time) and the other end where the application is location or place dependent. When using MOTEL in discovery mode you get an application that is at the location dependent end. Furthermore, it is a location dependent application where we mix real and virtual objects. In MOTEL we want the user to experience real objects (houses, streets, rivers etc), and we try to enhance the users experience (this can be seen as a form of augmented reality) with the means of a location aware mobile application. One recurring issue was how we can design the system to exploit the fact that the user is located in an area. Location aware applications can take advantage of this and use it to direct the user to real objects and features of the area, for example by guiding the user to orient herself towards looking at a particular characteristic of a cultural heritage object. We see the use of audio as an important enabler for this (somewhat similar to audio guides in museums). By using audio the user can listen to the audio and use her other senses (looking, smelling, feeling) and pay attention in the real context to real objects. This is an attempt to make a system that is different from a browser of cultural historical objects. Most of the time we do not want the user to have her focus on the small mobile screen, rather we want her to look at, and sense the real, enhanced by digital information enabled by the mobile application.

An important interaction design question thus is how can we design a locative interaction where the distribution of attention demand between the real and the virtual is such that we can take added advantage of the user being at the actual location (contrast this to building web pages). In our system we decided, as a first step, to solve this by adding audio in certain parts of the application.

8.3. *Learning triggers*

The second main outcome from testing was an issue about how to incorporate learning triggers. When should the application be interruptive and when should it be invisible and smooth? Building applications for the consumer market often entails building seamless and joyful experiences. However, it is not that simple when dealing with learning applications. On one hand we want particular triggers, or cognitive scaffolds for learning, and on the other hand we want a smooth user experience that does not interfere with the users experience of a location. What might be looked upon as an annoyance in one user scenario might be an important trigger for reflection and interruption in another (e.g. in order to generate breakdowns as an opportunity for learning). For example, the simple task of adding a geo-tag could be designed as a "one push" operation, or it can be designed as an operation where we trigger the user to label the annotation with a meta-cognitive label. In this way the tag is organized by adding semantics to it on the spot. This is a more laborious operation than the "one push" operation, but could be important as a cognitive trigger in a particular learning activity. In this way, encouraging the user to think about what the note and the tag meant leads the user into a meaning making process while being in context.

8.4. *Guide or serendipitous discovery*

One issue that quickly came up after my design crit was questions about how the application balanced between guiding a user to virtual hotspots and at the same time held on to the principle that users should only get access to information when in proximity of a hotspot? This question came up with regard to the functionality where is it possible to get all tags in proximity of your current location (in first version of MOTEL) and where users in discovery mode would be notified whenever a cultural heritage object was in their proximity (in the last MOTEL version). In the current model of MOTEL this notification is not supported in the software, but in the instructional design of a learning activity (e.g. a teacher tells his students to explore a particular area). Still, this is an issue that needs some support in the framework. One model is to guide the users by giving them hints and clues on what may be a hot spot (e.g. visual clues in a micro map on the phone without revealing what is actually there), but with the restriction that the user can only get access to the actual information when in proximity of the spot. In this way the system can take advantage of and stick to the policy that the users need to be at location, as well as the need to guide users to a certain extent.

8.5. *Design challenges*

These findings remain as a set of interaction design challenges for us whenever we are designing location aware mobile learning applications, and can be summarized as:

- How to take advantage of virtual tagging as a mean for transforming spaces into collaborative sites for learning?
- How to design a proper interplay between the information provided on the device/mobile device and the real objects at location?
- How to design for pleasant and smooth interactions at the same time as embedding learning mechanisms that require added cognitive effort from the users side (this could actually be formulated as a learning design dilemma)?
- How to balance between guiding and serendipitous discovery in a location aware application?

9. Mobile Learning Revisited

One thing in particular that has changed in recent years is the range of different mobile digital devices on the market and in possession and use among the general population. It is not only the computer, as in a desktop or workstation, that is the main digital tool in use. There is a plethora of digital appliances and devices (or “information appliances” as Donald Norman (1998) envisioned them) including portable computers (laptops and nettops[11]), PDA's, mobile phones (with various degrees of sophistication), digital cameras, digital GPS units (Global Positioning System), small portable game consoles (e.g. the Sony PSP or the Nintendo Wii), personal media assistants, etc.

We also see convergence in functionality and use. Digital devices are merging or adding features to their base — digital devices become multi-functional devices. Mobile phones have become mini computers (e.g. Symbian OS based phones). And in addition to being a game console, the new Sony Playstation 3 will be your new computer and home entertainment unit.

This leads to the issue of crossmedia communication and production. Today you can use Google maps on your mobile. Flickr, the largest online picture-sharing site, has made it possible to post photos using your mobile, and Instant Messaging clients and browsers are available for mobiles and game consoles. As a result, there is an ecology of online communities creating new services and technologies; commercial companies and hacker communities are gluing together existing systems, thus extending the use, while user communities provide feedback on design and participate in envisaging alternative/new uses and services.

What are the implications of these trends for mobile learning and for learning in general? I believe that these developments change the premises (the tools and practices) and conditions for learning. My research is motivated by how to make a productive learning infrastructure around these emerging mobile devices and practices (e.g. mobile blogging). This means the challenge is to both understand the changing conditions for learning and to be aware of the affordances of the technology in order to harness their synergy.

The MOTEL framework is continuously being developed and tested. Important questions we are asking include: How can knowledge about how students and professors organize their learning activities (and their life in general) and how they utilize technology be used in a meaningful way? How can we leverage existing knowledge and skills among students and professors in order to facilitate and guide students and professors in taking new and existing technology into use? What role should the mobile technology take? Mobile technology create somes conditions and comes with a set of affordances, but the question is what do we do with it. More specific in relation to designing mobile interaction we need to carefully contemplate where the learner's attention should be: on items in the application or outside the application such as a building? How are artifacts and mobility pivotal to productive learning, and how can we enhance and support learning activities?

Acknowledgment

This research is part of the TRANSFORM project (http://www.intermedia.uib.no/projects/transform), which is funded through a research grant from the Norwegian

[11]http://en.wikipedia.org/wiki/Nettop_(computer)

Research Council. The author would like to give a big thank you to Jo Wake and Barbara Wasson for giving me constructive feedback on earlier drafts of this paper.

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