Daniel Spikol

Playing and Learning Across Locations:

Identifying Factors for the Design of Collaborative Mobile Learning

Licentiate thesis
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Abstract

The research presented in this thesis investigates the design challenges associated with the development and use of mobile applications and tools for supporting collaboration in educational activities. These technologies provide new opportunities to promote and enhance collaboration by engaging learners in a variety of activities across different places and contexts. A basic challenge is to identify how to design and deploy mobile tools and services that could be used to support collaboration in different kinds of settings. There is a need to investigate how to design collaborative learning processes and to support flexible educational activities that take advantage of mobility. The main research question that I focus on is the identification of factors that influence the design of mobile collaborative learning.

The theoretical foundations that guide my work rely on the concepts behind computer supported collaborative learning and design-based research. These ideas are presented at the beginning of this thesis and provide the basis for developing an initial framework for understanding mobile collaboration. The empirical results from three different projects conducted as part of my efforts at the Center for Learning and Knowledge Technologies at Växjö University are presented and analyzed. These results are based on a collection of papers that have been published in two refereed international conference proceedings, a journal paper, and a book chapter. The educational activities and technological support have been developed in accordance with a grounded theoretical framework. The thesis ends by discussing those factors, which have been identified as having a significant influence when it comes to the design and support of mobile collaborative learning.

The findings presented in this thesis indicate that mobility changes the contexts of learning and modes of collaboration, requiring different design approaches than those used in traditional system development to support teaching and learning. The major conclusion of these efforts is that the learners’ creations, actions, sharing of experiences and reflections are key factors to consider when designing mobile collaborative activities in learning. The results additionally point to the benefit of directly involving the learners in the design process by connecting them to the iterative cycles of interaction design and research.

Keywords: Computer Supported Collaborative Learning, Mobile, Location-based services, Pervasive computing, Ubiquitous computing, Design-based research, Co-Design, Education, Games
Acknowledgements

With all undertakings in a team environment there are many people to thank for the support and inspiration that have made this licentiate thesis possible. Firstly, to my colleagues at the Center for Learning and Knowledge Technologies for providing the right atmosphere for fruitful collaboration that resulted in this work. Further, to the students, teachers, and staff who generously participated in the projects. Additionally, for the support from the expanded teams of the MUSIS II (VINNOVA and Telia Sonera AB), AMULETS (KK-stiftelsen), and the MIMEMO (Stiftelsen för Internetinfrastruktur) projects that supplied the financial support and research opportunities.

A lot of the work carried out would have not been possible without the help from the Mapping Växjö team who helped open doors and provided the playing fields for the research. In addition, they provided physical training for the body to support the mental work.

I am indebted to my main supervisor Marcelo Milrad, who has provided me with the opportunities to re-enter research by creating an inspiring and nurturing environment that enabled me to learn by doing and playing. Thanks also to Simon Winter, my supervisor, for providing needed insights that have challenged me to think differently and more deeply about the key issues in my work. And to my colleague and fellow doctorate student Arianit Kurti, who continues to be an excellent sparring partner.

None of this work would have been possible without the support of my family, especially the patience, understanding, and love of my wife.

This thesis is dedicated to the memory of Ante Jamtlid and family, he asked me what was next and this is the start to answer that question.
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1 Introduction

Over thirty years ago a group of computer scientists at Xerox’s PARC (Palo Alto Research Center, Inc) proposed a design idea that is still changing the world. They described the idea as a personal dynamic medium the size of a notebook (the Dynabook) which could be owned by everyone and could have the power to handle virtually all of its owner’s information-related needs (Kay, 1977). A few years later, greatly influenced by the Dynabook and contemporary educational theories, Seymour Papert developed LOGO, a programming language that recognized that learners are active builders of their own intellectual structures who could benefit from having the opportunity to construct these structures on the computer screen (Papert, 1980). Ideas and research continued to brew in Palo Alto and elsewhere and in the following decade researchers began to conceive of a new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background, invisibly enhancing the world that already exists (Weiser, 1991).

These ideas from the last three decades may seem like lofty research goals until you begin to consider that at the time of writing this thesis nearly half the world, 3 billion people, have access to a mobile phone (GSM World, 2008), and that global coverage is roughly 80% (GSM World, 2008). By 2015 or sooner nearly 5 billion people will have acquired affordable voice, data, and Internet service through mobile devices. This should be compared to the penetration of PCs, which roughly 1 billion people have access to globally (Nationmaster, 2008). This rapid adoption of mobile technologies offers an enormous potential for improving and enhancing our lives and has already been shown to reduce the digital divide by allowing developing countries to leapfrog over some generations of technologies (BBC, 2008). An increase of merely 10% in the penetration of mobile devices in developing nations raises the GDP by 1.2% (GSM World, 2008).

Knowledge acquisition and learning can benefit from the adoption of these devices across different societies, thus offering enormous opportunities for learning, entertainment, and information-sharing. One of the essential requirements in our rapidly changing society is to prepare learners to participate in socially organized activities, a situation where mobile technologies may come to support (Järvelä, 2006). With their global penetration and relatively low cost sophisticated mobile phones with Internet connectivity, cameras, GPS, and other multimedia features rival the computational power of laptops. These mobiles can be seen as the current “Dynabook”, something that changes the way we have to think about learning and work. Work, and to an even greater extent learning, can overlook these capabilities. Lankshear and Knobel (2006) argue that mobile and wireless technologies and new media might be integrated into current school educational activities since they are transforming and defining new literacies in teaching and learning. This gap between how people learn and use information technology inside and outside of professional and educational settings is already noticeable. Clear indications of this trend can be seen in web communities such as YouTube, Flickr, Facebook and Twitter which enable seamless integration between mobile devices and computers, driving people to share experiences and to socialize across different settings.
1.1 Research question

The research presented in this thesis investigates the design challenges that pervasive and mobile technologies raise for supporting collaboration in educational settings. Mobility offers new dimensions to support and promote meaningful learning activities that include features such as connectivity, social interactivity and context sensitivity (Klopfer et al., 2002, Sharples et al., 2008). These mobile technologies can offer opportunities to promote and enhance collaboration by enabling learners to engage in activities across different locations. These different settings provide innovative ways for people and devices to interact by enabling learning to take place beyond the walls of the classroom and the screen of a computer. These new settings that combine mobile tools in different locations present design opportunities for multiple kinds of collaboration to support different aspects of the learning process (Price et al., 2003). Based on this background the research question to be discussed in this thesis can be formulated as follows:

*Which are the most relevant factors that influence the design of mobile collaborative learning?*

Mobile devices offer a chance to enhance collaboration by affording people the opportunity to engage in learning in the context of activities that typically involve problems and tasks as well as other persons in different environments and cultures (Sharples et al., 2008). My particular research seeks to identify and begin to formulate design guidelines that describe how collaboration can be enhanced for the development of mobile learning that takes into consideration the mobile users’ context of tasks and environment. In order to identify these design factors the research uses empirical results and analysis across several projects combined with Computer Supported Collaborative Learning (CSCL) and human-centered design. The objective of this thesis is to identify design factors that need to be considered when using pervasive and mobile technologies to promote CSCL.

1.2 Research settings

The research efforts that have supplied the empirical data for my thesis are based on three externally funded projects. These projects have enabled me to test and discuss my ideas about which factors are important for supporting mobile collaborative learning. The thesis is based on a collection of four papers that have been published in two refereed international conference proceedings, a journal paper, and a book chapter.

The first project, MUSIS (Multicasting Services and Information in Sweden), provided the initial research into how mobile devices can be used for supporting learning and teaching and by enhancing collaboration. The research within this project was carried out with university students and teachers. In addition, the project was conducted with industrial and other academic partners and funded through a grant from a national agency.

The second project is AMULETS (Advanced Mobile Ubiquitous Learning for Teachers and Students), whose goal is to investigate how new technologies can be integrated into formal and informal education and how new teachers can be trained to leverage these techniques. The different activities in AMULETS were conducted with elementary school students and university teacher students in formal and informal
settings. AMULETS is partially funded by a national agency and is part of a larger national initiative with two other universities.

The third project, Skattjakt (Swedish for ‘Treasure Hunt’), explores the creation and deployment of mobile games with students and teachers. Skattjakt is an independent subproject to AMULETS. The mobile games developed in this project have been inspired by the ideas behind treasure hunt activities and the sport of orienteering, a traditional Scandinavian running sport involving navigation with a map and a compass. One of the goals of Skattjakt has been to investigate how the implementation of new learning activities can be used to analyze and understand how co-design impacts the future design of new activities.

1.3 Structure of the thesis
The structure of this thesis is as follows: Section 2 briefly describes the theoretical foundations of my research from the standpoint of collaboration and context. The section presents current trends in CSCL from a design perspective. Section 3 looks at the design-based research approach, exploring how iterative design can support the design and development of CSCL theories. Section 4 presents the research activities and the empirical results across the three projects. Section 5 discusses the results and identifies the factors for the design of collaborative mobile learning. Section 6 concludes the work, summarizes the findings and points towards future work. The appendix of the thesis is the collection of the four papers that account for the main results.
2 Theoretical foundations

One opportunity that learning with mobile technologies offers is the ability to create activities and situations in different places, outside the classroom and not only in front of the computer. These mobile technologies provide rich digital tools with connectivity for the creation, use, and sharing of artifacts and visualizations that can be used outside and inside various learning settings. These are not new ideas to computer science or education, but they echo the shift away from machine-centered automation to user-centered services that focus on the interaction of people to other people and to machines (Shneiderman, 2002).

In March of 1962, Bauer (1996) recounts that he in the United States and Dreyfus in France simultaneously defined Informatics, respectively, as “the science of information handling” and “the modern science of electronic information handling”. Bauer and Dreyfus recognized the shift from computer machine data to the value of information in society. Langefors (1978) explored this value as he began to formulate theories of information systems. This shift from data to information and from machine to person is generally described as the transition into a knowledge- and information-based society, focusing on creativity and innovation as key goals for all of society (Drucker, 1994). Creativity and innovation became paramount, and learning became an integral and inseparable part of “adult” activities in the professional world where computers are everyday tools, utilized for learning, creativity, and innovation (Milrad et al., 1999). These shifts created the need to better understand how groups of people collaboratively worked with computers. Computer-supported collaborative work (CSCW) developed as a design-oriented field of research where field studies and development are combined (Kensing & Bloomberg, 1998). CSCW is a generic term which combines the understanding of the way people work in groups with the enabling technologies of computer networking and associated hardware, software, services and techniques (Wilson, 1991). The knowledge and information society brought computers into the classroom. New and expanded approaches were needed to support knowledge acquisition in professional and educational settings. One of these is computer-supported collaborative learning (CSCL), which is an emerging branch of learning sciences concerned with studying how people can learn together with the help of computers (Stahl, et al., 2006).

In the following sections I elaborate on how collaboration and context can support and enhance computational support and learning in a wider variety of educational settings. The context where learning happens needs to be considered when mobility enables users to explore the world beyond the classroom and the screen of a computer. The initial ideas of a design framework are presented, illustrating collaboration in context that provides a basic structure for exploring CSCL with mobile technology.

2.1 Learning and collaboration
The study of learning and collaboration has a background in diverse theories of cognition and psychological development. These theories explore how different types of interaction between peers and experts are integral to learning and cognition. The Piagetian school supports peer-to-peer interactions between “equals”, enabling conversations that can result in cognitive restructuring, while Vygotskian theories can
be seen to support a peer-to-mentor interaction, where the mentor, the more “able” partner, facilitates the development of knowledge and skills by scaffolding activities (Price et al., 2003). Both schools advocate social interaction as playing a key role in learning, while Vygotsky’s work introduced a wider theoretical development of “cultural psychology”, which together with anthropology and cognitive science formed the basis of situated learning (Lave & Wenger, 1991). Situated learning is a general theory of knowledge acquisition based on the notion that learning (stable, persisting changes in knowledge, skills and behavior) occurs in the context of authentic activities (Lave & Wenger, 1991). Technological advances make it possible to expand learning beyond the four walls of the classroom by allowing interaction in the real world and bringing new interactions back into the classroom, thus providing greater opportunities for authentic learning (Hooft & Swan, 2007).

Learning can be seen as a social process; it is created in collaboration between people and supported by technology, from chalk, blackboards and books via ballpoint pens, calculators and computers to, currently, mobile devices. Brown and Duguid (2000) argue that the view of technology should be shifted from being seen as a cognitive delivery system to being considered as a means to support collaborative conversations about a topic. In this process learning can be seen as enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs and other norms (Hoppe et al., 2005).

For my thesis I have focused on the social constructivist view of learning, since I am mainly concerned with supporting and enhancing collaboration between people with the use of technology. This view of learning places its emphasis on the negotiation of meaning and on processes of joint construction of understanding. Social constructivism considers the role of the collaborative rather than the conflictual process, and particularly the role that conversation plays. The group becomes the focus of analysis and the emphasis is placed on socially constructed properties of interaction, rather than on individual performance (Littleton & Häkkinen, 1999). Collaboration provides part of this framework that guides and supports the learner, but the context of the situation also needs to be considered.

2.2 Learning context

The role of context plays a crucial role in the discussed theories of learning and in the role of research in the computing community. The main idea is that learning is fundamentally a social phenomenon that needs to be placed in the context of the learners’ lived experience (Wenger, 1998). The ideas of context and context-awareness were pioneered by Weiser with his and fellow researchers’ ideas of integrating computers seamlessly into the world at large. The goal of their research was to “enhance computer use by making many computers available throughout the physical environment and making them effectively invisible to the user” (Weiser, 1991). Physical location becomes the first basic block in understanding context. The ideas behind context have been expanding since Weiser and Hull and their colleagues (1997) defined context as “aspects of the current situation”. In addition, Brown (1995) defined context as “elements of the user’s environment which the computer knows about”. Some of the original examples that Brown et al. (1997) developed illustrate how handheld devices could be made aware of what room or location outside they are in and provide relevant information about activities or services at the location in the
workplace or for tourists. Ideas on ubiquitous computing progressed and the definition expanded, Dey and Abowd (2000) refer to the context as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”.

Context plays multiple roles in the interaction between physical and social locations, tasks and activities and the user’s situation. In the scope of this thesis I have chosen to use the definition of context in connection with work conducted with colleagues as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment” (Kurti et al., 2008). Therefore, this definition of context relies upon a three-axis structure consisting of the following attributes: location & environment, activity & task and social relations (personal & interpersonal). The attributes of this structure are interdependent, meaning that information about who the user is, where the user is, what the user is doing and the interplay between these activities needs to become valuable inputs to the design process (Kurti et al., 2008).

2.3 Ubiquitous and pervasive technologies

It is important to briefly note the difference and similarities between ubiquitous and pervasive technologies, since the terms can be loosely interchanged and are closely related in research. The original idea behind ubiquitous technology was to integrate information processing into everyday objects and making it recede into the background of our lives (Weiser, 1991) through invisible and seamless technology. Pervasive computing can be thought of as tangible devices, designed to enable the real-time logging, recording and collecting of data forms (Rogers & Price, 2007).

Ubiquitous and pervasive computing share many of the same features and rely on active and passive sensors like GPS, or more specialized sensors like chemical ones or temperature. They are always connected and turned on; they generate tangible data, provide seamless deployment of interaction and can be single and multi-purpose. Cuff et al. (2008) explain a shift from sensors and devices in the laboratories of computer scientists into the backpacks, purses, and coat pockets taking the form of mobile phones. These mobile phones set the groundwork of Weiser’s vision of ubiquitous computing. For this thesis I will use a wide definition of pervasive technology since it primarily involves mobile phones.

2.4 Collaboration in context

My research focus is on using mobile technologies that support a range of different collaborative combinations rather than focus mainly on one form of collaboration around the computer or small handheld mobile screens. In the research results presented in my thesis each one of the three projects has used a combination of mobile phones and computers to explore collaboration across different locations. This approach enables learners to interact more freely than with personal computers and to engage in a variety of interactions and collaborative modes. That depends on the context in which learning occurs, enhancing situated and collaborative learning. Research indicates that students are facing difficulties in applying concepts learned in formal educational contexts. Therefore, by providing concrete examples of abstract concepts in the context of where they are happening, they can play an important role in learning. It is not the abstraction of knowledge that derails the learning process, but the circumstance that these abstract concepts are not presented with examples in context (Brown et al., 1989).
Collaboration and context play key roles in the design of mobile learning activities (Spikol et al, 2008). Mobile devices are prevalent in people’s everyday lives and can be easily used in the classroom and in the field, providing more opportunities than computer labs (Crawford & Vahey, 2002). Roschelle et al. (2005) suggest that articulating a design framework that spans many mobile CSCL activities can be a key contribution to further work. Furthermore, collaboration needs to be seen from the perspective of shifting away from the outcomes of collaborative work towards analyzing interactions as means of gaining insights into the processes of collaborative learning (Littleton & Häkkinen, 1999). Dourish (2004) raises the importance of looking at context through interactions, focusing on the question “How and why in the course of their interactions do people maintain a mutual context for their actions?” One perspective for researching mobile learning has its point of departure as Collaboration in Context. This concept can be used to form a generic framework that takes into consideration the challenges of collaboration and context between diverse activities, locations, people and technologies. Collaboration in context is the suggested approach for identifying the design factors for supporting mobile collaborative learning.

2.5 The initial framework

In order to support the ideas of collaboration in context a generic framework is suggested that takes the three-pole structure of location, activity and social relations into consideration (Kurti et al., 2008). This framework has been developed and adapted from work done with colleagues at CeLeKT. In Figure 1 the surrounding circular ring of arrows defines the context where the activities are taking place at a given moment in time. The circle can be seen as the cultural and social context that enables learning modalities and styles, recognizing the importance of social and network interaction between people. Broadly speaking, context is continually negotiated and refined by people engaged in action with artifacts and cannot be separated from this (Winters & Price, 2005).

Figure 1 Context model adapted from Kurti et al., (2008)
The Learning Activity System (LAS) is a “black box” computer system providing the technological support for the collaboration between learners in the context where these learning activities are taking place (see Kurti et al., 2008, for a more elaborate discussion of the LAS). These conceptual ideas have been used for guiding technological development and implementation. The LAS relies upon the use of different software components and pervasive technologies together with sensors in order to contextually support activities and collaboration across the different axes. Figure 1 only illustrates individual interaction and is not representative of collaborative activities. Figure 2 below provides a more accurate framework of collaboration where multiple contexts and interactions are happening face to face and through computer-mediated technology.

2.6 Expanding the collaboration in context framework

Figure 2 presents the extended framework that takes into consideration the focus of my work by identifying the design factors needed to foster collaboration between groups of learners across different learning contexts and landscapes. It illustrates how mobile technologies can present this environment on the individual and group levels, keeping in focus the pedagogic goals of learning but allowing exploration, conversation and meaning-making to happen. The outer ring represents the overall learning activity. The inner ring illustrates some of the different locations where mobile and pervasive technologies can be used to enhance collaboration and learning, including school, work, home and outdoors. I have included pervasive sensors in the framework providing opportunities for real and virtual locations to be connected.

Figure 2 Expanded framework for collaboration in context
Examples of the application of this framework can be seen for example in the AMULETS project, where teams of students interacted using a public web camera in the town square (See section 4.3). Each of these locations can include specific learning activities and groups of people to collaborate with. Additionally, collaboration can happen across space and time throughout the entire activity.

2.7 Playful learning and current mobile games

Mobile and pervasive technologies provide new opportunities for collaboration by allowing the different contexts of activities and social interactions across locations. However, these situations and actions provide challenges for the design of learning activities that go beyond individual learning in front of computers. There is an extensive history of games in education from early simulations to immersive worlds for learning which ones support social constructivist theories (Freitas, 2006). Additionally, the recent proliferation of mobile games has made them into a fertile ground for the development of new resources to support learning (Facer et al. 2004).

Mobile games encourage children to get involved in different tasks such as exploration, content generation, collaboration, problem-solving and navigation in space; all these activities can be seen as important components that support a wide variety of cognitive and social skills. Game-based learning offers good opportunities to investigate collaboration. The following six projects present a brief overview of mobile games that have successfully explored playing and learning across locations.

Environmental Detectives is an early mobile game that used personal digital assistants (PDAs). The game has engaged high-school and university students in a real-world environmental consulting scenario constructed to immerse players in the practices of environmental engineers, giving them a “virtual practicum” experience, similar to working on an environmental research team. Students play environmental scientists investigating a rash of health concerns on site linked to the release of toxins in the water supply, a scenario loosely based on actual historic situations. The main focus of the game was on planning an effective investigation that balanced quantitative and qualitative data. (Klopfer et al., 2002)

The Ambient Wood project was designed to enable children to switch between the experiences of the physical world (for example, observing a butterfly drinking nectar from a thistle) and to reflect upon the ecological processes behind this interdependency (for example, pollination). The learning experience was designed to encourage children to explore and hypothesize about different habitats found in a forest through the use of pervasive and mobile devices placed outdoors. Mobile devices and visualization tools were provided for the children to access and share contextually relevant digital information (for example, the animation of seasonal changes) when indoors and outdoors. (Price et al., 2003)

Savannah is a mobile game that re-creates the African savannah outside on local school grounds. The game consists of two related areas of activity. In the first, children are able to play at ‘being a pride of lions’ outside in a playing field (100m x 50 m), interacting with a virtual savannah and exploring the opportunities and risks to lions in that space. Children are given global positioning systems (GPSs) devices linked to personal digital assistants (PDAs) through which they ‘see’, ‘hear’ and ‘smell’ the world of the savannah as they navigate the real space outdoors. The
second playing field, the ‘Den’, is an indoors space where children can reflect on how well they have succeeded in the game, access other resources to support their understanding and develop strategies for surviving as lions in the virtual savannah (Facer et al., 2004).

Frequency 1550 is a historically based game in which groups of students are competing acting as pilgrims in old Amsterdam while trying to find a missing holy relic. Each team has members located at the headquarters and exploring the present-day streets of the city. They communicate via videophones and use a GPS-equipped mobile phone for the game and for position-tracking while at headquarters they have a laptop connected to the Internet. The teams at headquarters track all the teams and can direct their own team in the street to solve the mystery (Raessens, 2007).

The HP Mediascape project originated from collaboration between Hewlett-Packard, the University of Bristol and The Appliance Studio with funding from the UK Government Department of Trade and Industry. Mediascape experiences are context-aware rich multimedia delivered to mobile devices that specify the relevance they have to the physical situation—that is, a person’s context (Stenton, 2007). A multitude of Mediascapes have been developed for education and for general purposes such as art exhibits and location-based experiences. Several projects have been launched from this initiative, including CreateAscape, designed for educational use, and the general Mediascape, an open toolkit for everyone.

The COLLAGE (Collaborative Learning Platform Using Game-like Enhancements) project brings to secondary school students and their teachers a mobile learning platform for context-dependent games. It is fun and interdisciplinary, offering collaboration and challenge beyond the four walls of the classroom, which creates new learning opportunities. The COLLAGE platform supports the authoring and playing of a board-like game on a site of educational interest. The game is played with the aid of mobile learning technology (mainly mobile phones, PDAs and GPS technology) involving direct communication with players situated on site or in the classroom (Sotiriou & Chryssafidou, 2006).

The examples described above show results regarding the use of mobile games in informal educational contexts that investigate collaboration. The Mediascape and COLLAGE projects additionally offer opportunities for the learners and users to become involved in the design process. This involvement of the learner becomes paramount for my research and results.

2.8 Research need
In this chapter I have discussed the theoretical foundations that position my research in the realm of CSCL, focusing on how people learn together with collaborative mobile technologies. Using the collaboration in context framework for the different educational activities that make up the empirical work provides valuable insights for identifying relevant factors for mobile collaborative learning. Understanding how mobility offers fertile ground for collaborative educational activities with the discussion of the previous six examples gives insights into the benefits of this approach. In the next section I discuss the methodological approach used for the design and evaluation of the empirical work that will be described in chapter 4.
This chapter describes those aspects related to methodological issues connected to the research efforts conducted as part of this thesis. The implementation of the collaboration framework in context presented in the previous chapter requires different methods to validate the design of mobile learning experiences. In order to identify the design factors for supporting mobile collaborative learning I have made use of different approaches, such as field and design experiments, in order to capture the complexity of people learning and playing at different places. The goal has been to make sense of multiple interactions between people and technology in collaborative learning settings. I have used the different projects to gather a broad range of data to identify these factors.

Stahl et al. (2006) have characterized three types of general approaches for understanding computer supported collaborative learning; the experimental, the descriptive, and iterative design. The experimental approach compares interventions to a control situation where interactions are measured, while the descriptive case analysis can be seen as qualitative, where video, text and other ethnomethodological means are data-driven seeking to discover patterns in data. My work has adopted the iterative design approach. The strength of following this tradition is that it is driven by the interactions between the learners, the artifacts and the systems. Design-oriented researchers continuously improve the artifacts intended to mediate learning and collaboration through informal observations and stakeholder engagement (Stahl et al., 2006).

The work presented in my thesis is line with this iterative approach, which additionally raises the following challenges in order to provide an answer to my main research question:

- How can we facilitate teaching and learning with mobile services through design?
- How can we utilize design processes to support different collaboration modes across indoor and outdoor learning environments?
- Which different design methods can be used to promote collaboration in mobile learning activities?

3.1 Methodological considerations

Herbert Simon wrote: “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (Simon, 1969). His realization of the importance of constructed artifacts and the role they play in research can still be applied when working with complex environments such as those we face in “mobile learning”. Wenger (1998) clearly points out that, learning happens, design or no design, and there are few more urgent tasks than to design social infrastructures that foster learning. In the information society working and living rely on collaboration, creativity, the definition and framing of problems as well as dealing with uncertainty, change and distributed cognition. Education needs to prepare creative and productive students for such a world (Fischer & Konomi, 2005). The challenge is to use design...
methodologies to support the learning process taking into consideration the new contexts of collaboration afforded by mobile and pervasive technologies. In the following sections I discuss different design approaches that can provide some answers to the above questions.

3.1.2 Human-centered design

Interaction design is defined as the process of designing interactive products to support the way people communicate and interact in their everyday and working lives (Sharp et al., 2007). What makes interaction design different from other types of interaction like human-computer interaction is that it is concerned with the wider implications of practice opposed to the design, evaluation practices, and performance of interactive computing systems. The process of interaction design is based on the user experience of the product in the context it was designed for. Sharp et al. (2007) define the process of interaction design as having these four basic activities:

- Identifying the needs and establishing requirements for user experience
- Developing alternative designs that meet these requirements
- Building interactive versions of the designs so that they can be communicated and assessed
- Evaluating what is being built throughout the process and the user experience it offers

These four activities focus on user experience while being iterative and informative for each activity. One of the roots of interaction design is Participatory Design, a movement founded in the 1960’s and 70’s that can be described as a work-oriented design approach with democratic participation and skill enhancement (Ehn, 1993). It grew out of researchers’ and the workers unions’ desire to create an industrial democracy in Scandinavia where the workers’ skill and product quality could be addressed with the introduction of new computer-based systems. Ehn (1993) when reflecting argues that the design process must be organized in a way that makes it possible for ordinary users not only to utilize their practical skill in the design work, but also to have fun while doing so.

Participatory design (PD) can be seen as a social innovation, described by Rogers (1995) as the process by which results are communicated through certain channels over time among the members of a social system. What is important about the early roots of participatory design is the realization that the introduction of systems, like any innovation, is a cultural shift between people and technology, with the emphasis on people. In other words, the study of the diffusion of innovation is the study of how, why, and at what rate new ideas and technology spread through cultures. PD has influenced different design theories and practices because of its focus on the human experience. Co-design can be considered an offspring of PD and it can be defined as a highly facilitated, team-based process in which teachers, researchers and developers work together in defined roles to design an educational innovation. The team realizes the design in one or more prototypes and evaluates each prototype’s significance for addressing an educational need (Penuel et al., 2007). The co-design process relies on teachers’ ongoing involvement with the design of educational innovations, which typically employ technology as a critical support for practice.
Co-design can be seen as a collaborative effort that places importance on the designs reflecting the core values of the users. Over the last two decades, stakeholders, users, and designers of workplace technologies have considered how best to design systems that bring innovation into these environments through various design processes. Penuel et al. (2007) point out that co-design has close affinities with participatory design and with user-centered and scenario design. When used in the educational domain, co-design shares values with learner-centered design and design-based research. Where co-design differs from exploratory research on learning innovations is that it depends critically on whether the team of people working on the project meets a specific challenge defined at the start of the project. Co-design, like the previously mentioned design processes, involves iterative cycles of development where concepts are tested and refined, ranging from paper prototypes to the final system. What is lacking from these design approaches for education at times is the direct and active involvement of the learners in this process. The practices of Cooperative Inquiry and Learning by Design are methods used to explore these iterative cycles of working with adults and children to create innovative technology for children (Guha et al., 2004 and Kolodner et al., 2003). What can be observed from these human-centered design approaches is that design plays a key role in the efforts to foster learning, create relevant knowledge and advance theories of learning in complex technological settings.

3.1.3 Iterations and the design process
One of the primary aims of design-based research (DBR) is to develop domain-specific theories in order to understand the learning process (Mor & Winters, 2007). The Design-Based Research Collective group (2004) argues that design-based research blends empirical education research with the theory-driven design of learning environments. This can be an important methodology for understanding how, when, and why educational innovations work in practice. I consider it as a suitable methodological approach for the field of mobile learning, since DBR attempts to combine the intentional design of interactive learning environments with the empirical exploration of our understanding of these environments and how they interact with the individuals (Hoadley, 2004). Design-based research follows an iterative cycle of identifying, developing, building and evaluating similar to Interaction Design and introduces theory building and expansion into the cycles. These iterative and human-focused design processes form a key to understanding how to promote collaborative learning with technologies.

3.1.4 Meta-design and constructivism
Fischer and Ostwald (2003) use the term Meta-design to describe the role of users in different design approaches. What the approach offers is the view of users as active participants and designers throughout the lifecycle of the design product. Meta-design approaches characterize objectives, techniques and processes for creating new media and environments that allow the owners of problems to act as designers (Fischer & Ostwald, 2003). They engage the users in creating knowledge rather than being restricted to instruction or consumption of existing knowledge. They break down the design approach into design time and use time. Table 1 illustrates the differences in the approach that affect the user involvement in the design process and their relationship to the use of the final artifact and environment.
Table 1 – The role of users in different design approaches based on Fischer and Ostwald (2003)

In professionally dominated design users have no input into or control over the artifact. Participatory design offers the users input during the design process, but once the artifact is in use it is difficult to fit it to new needs. Meta-design provides the users with active participation in the design phase, and during the use time they can continue to evolve the artifact to different uses. Meta-design can be seen to complement the constructivist approach by giving learners the ability to construct meaning while actively influence the evolution of the artifacts together. Allowing the learners to participate in social and authentic tasks together contributes to form communities of practice (Wenger, 1998).

3.1.5 Case, field studies, and action research

Evaluation methodology is a systematic approach to conducting at least one complete phase of system development, consisting of a set of guidelines, activities, techniques and tools, based on a particular philosophy of system development and target system (Wynekoop and Russo, 1997). Field studies, case studies and action research take place in real-world settings and provide rich data and first-hand experience (Kjeldskov & Graham, 2004). Participatory Design was influenced by action research conducted in these settings. I have chosen to use a design-based research approach in connection to my particular efforts, since the work presented concentrates on the questions of epistemology and innovation and not on the adoption of effective systems for work. The focus of inquiry in DBR is on learning and how it is affected by educational design instead of work-related objectives. Obviously, any research tool used would have to be calibrated towards this perspective. Second, DBR is distinguished by a tight, dynamic and continuous interaction of design, experimentation and analysis. In contrast with other approaches, it is not unusual for data collected in one week to be quickly analyzed and used to redesign the session for the following week. This requires agile methods of collection and analysis, which can fit into such an intensive cycle (London Knowledge Lab, 2008).

3.2 Methodological approach

The goal of this thesis is to identify design factors to support mobile collaborative learning. The to be work presented in the next chapter requires specific methods to analyze the different projects for the detection of these factors. The collaborative mobile learning activities and the outcomes of my work took place in classrooms and other educational settings as part of normal curricula and informal learning. Each of the three projects was developed and deployed in iterative cycles with the active involvement of researchers, teachers and students. The projects were evaluated using ethnographic approaches that combined experiencing the mobile activity, and in the later project cycles of co-design, with teachers and students. Field notes, surveys, extensive interviews, documentation and the collection of artifacts and of data from the system were used. The experience of the technology and its impact through the entire learning activity were considered including usability and the utility of functions.

The research efforts to be presented in the following chapter were conceived, implemented and inspired by the ideas and rationale suggested by the different methodologies presented earlier in this section. These efforts presented are more
similar to ethnography than to quantitative studies; the emphasis is on design processes as planned, observed and reported in their natural settings. In my particular efforts the different educational activities were developed together with teachers and students based on prior cognitive, educational and technological research of the learning contexts. Different scenarios were implemented and a variety of data sets were collected and analyzed to determine the success of the designs. Since a successful educational design should operate as an integrated system, the critical elements of the design were identified and their interactions in the specific educational setting were analyzed. If those elements were not working in the expected way, then the design was modified based on the findings, and a revised prototype was implemented. In this sense, design-based research has some of the aspects of a formative evaluation, especially as it informs the next version of the interactive learning environment. In the research efforts to be described in the coming section, I have used design-based research as the means of exploring how collaboration and context can be used to support the design of innovative mobile learning activities.
4 Overview of research efforts

This chapter presents four papers that illustrate the research efforts that I have been involved with and that have supplied the empirical data for this thesis. The work is primarily based on two large externally funded projects. The first project, MUSIS, was funded by VINNOVA and provided the initial research on how mobile devices can be used for supporting learning and teaching. The Knowledge Foundation of Sweden funded the second and third projects AMULETS and Skattjak, with additional support from the Internet Infrastructure Foundation of Sweden. The work in these last two projects was conducted primarily in the Young Communication project, where the goal is to investigate how new technologies can be integrated into formal and informal education together with novel ways of conduction teacher training. The following papers reflect my journey, starting from traditional design point of view and evolving towards an inclusive view that enables a different exploration of collaboration that is more in line with human-centered design and the goals of design-based research presented in Chapter 3.

4.1 Papers

Paper I

Paper II

Paper III

Paper IV

4.2 Paper I
This paper reports the results of the MUSIS (Multicasting Services and Information in Sweden) projects. The paper reports on the two iterations of the MUSIS projects, the first project taking place in 2005 with 41 university students and the second in 2007 with 21 students. During both project periods we investigated the use of mobile phones across private use and school use at the university. The project looked at how
to provide different types of rich media push services to the phones. The students were able to subscribe to different channels to receive content that ranged from administration logistics to course material and entertainment. This project explored the gap between mobile technologies and new media that are prevalent outside of school in the forms of social networking and entertainment and how some these services could be used in the classroom. This raised the two following questions that were investigated in the paper. What are the implications of using mobile computing and wireless communication for supporting learning and teaching? What new scenarios and applications will emerge? The studies were designed to explore the patterns of use of a number of mobile services experienced by students in a university campus environment and other locations of their choice. In the second trial these patterns of use were extended with the ability for students and teachers to multicast learning artifacts to each other to support collaboration. The impact on learning itself was not measured, nor would it have been possible to measure meaningfully when the devices were used for such diverse purposes. Phone-optimized content was heavily used, and there was a clear request from students that more resources be made available in this format, including administrative information from the universities.

The results of the two trials highlighted the importance of designing applications and services that are easy to use from different places and could be completed in short periods of time. The multicasting features of MUSIS provided some understandings of how learners in motion could take advantage of these services for sending and receiving content in their daily life between classrooms, workshops, libraries, in the city and at home. The results suggest that in higher education the challenge for social technologies that support pedagogical goals require more than the design of services to connect people and content. This is supported by the trials and the different degree of engagement of the instructors in both periods of the project. The results of these efforts pointed me in a direction away from providing services towards exploring how mobile devices could be used to support collaboration between learners and learning. It was clear from the results of our efforts that more than services are needed to better support the social requirements and that just the delivery of existing learning materials to the mobile device was not enough. This marked a shift from just exploring services to looking at how collaboration can be used in the learning environment and what types of systems and tools need to be designed and implemented.

4.3 Paper II

This paper presents the work connected to the AMULETS (Advanced Mobile and Ubiquitous Learning Environments for Teachers and Students) project. We describe how the ubiquitous computing solutions developed to support learning activities in the field of history that took place in the city and in the classroom. We considered the efforts as being an attempt to create innovative socially situated exploratory learning experiences throughout elaborated learning sequences supported by ubiquitous technologies. Within the context of our efforts, the notion of socially situated extends to the idea of learning activities guided by the context in which they are taking place. The learning materials were co-developed with the teachers, and the structure of the activity was game-inspired.

Twenty-nine 5th-grade children (11-12 years old) participated in this trial, which was conducted during the fall 2006. The content explored in this activity was related to the
field of local history, which is part of the school curriculum. The physical settings where the trial took place were the main square and the museum of history in the city of Växjö, Sweden. The class was divided into 3 workgroups and each of these workgroups split into an indoor and an outdoor group with about 5 students in each of the groups. The students in located in different places needed to collaborate and negotiate tasks together using smart phones and computers that enabled text and image exchanges.

In this paper the different located activities between the indoor and outdoor groups gave us insights into how to further design socially situated exploratory learning that will enable us to explore collaboration factors between peers and groups supported by different technologies. This trial highlighted the need for a stronger role for co-design where the teachers were more involved in the design and development of the learning materials. It additionally raised the issue of how to begin to make the students more active in the creation of their own learning materials. The activities in the field and at the museum specifically looked at modes of collaboration between learners in different locations. The active involvement of the teachers in design of the activities enabled the students to work with data collected and to reflect about the learning experiences with the tools developed. The different collaboration modes gave us an insight into how to design the next trial, detailed in Paper III.

4.4 Paper III

In this book chapter we describe the continuing efforts related to the design, implementation and evaluation of innovative educational activities supported by ubiquitous computing in the AMULETS project. This book chapter presents the three AMULETS trials completed during the period of 2006-2007. The pilot trial that took place in June of 2006 enabled 26 fourth-grade students in groups to explore the forest. In the second trial, Växjö Square (December 2006), 29 fifth-grade students in 3 groups were located and worked simultaneously in the city center and at a museum. For the third trial, 21 teacher students from the university (April 2007) in different groups collaborated to identify trees and with their teammates in a computer lab. Additionally, they participated in workshops to design future mobile learning scenarios for students. The main argument of the chapter is that the design of innovative mobile learning activities needs to be guided by collaboration in context supported by pervasive technologies. To support this claim the collaboration in context framework (see Chapter 2.5) was used to how to support novel mobile learning scenarios. This book chapter shows how the initial framework provided the designer with conceptual tools to tackle the challenges of innovative mobile learning activities. Working together with the teachers and students gave us the opportunity to design for learning activities at authentic locations using meaningful content of relevance to the school curriculum. In addition the design-based research methods enabled us to explore how to create learning activities that integrated the teachers and the university students in the design process. These ideas are illustrated by the presentation of the results from the three trials.

The book chapter provided an opportunity to reflect on the design process and with the approach of design-based research we will able to keep refining the learning experience to explore and enable collaboration in context. In the first AMULETS trial the students collaborated in the field together, in the second trial the students collaborated across remote locations, and in the third trial the teacher students shifted
locations so that both groups could experience the field and the indoor location. Additionally, the teacher students participated in future technology workshops that enabled them to design and discuss how they could integrate these technologies into practice later on. In summary, this book chapter illustrated the benefits of involving the teachers and learners in the design process providing opportunities to discuss and reflect on the design of mobile learning systems. In this paper we began to expand the methods to include the learners into the design process and this provided an impetus to expand these practices for Skattjakt.

4.5 Paper IV

This paper presents how co-design can offer insights into the design and evaluation of a mobile game called Skattjakt (Swedish for ‘Treasure Hunt’) and the benefits it can have for future learning activities. Skattjakt is part of the AMULETS project, but its focus is on informal types of learning that have slowly been integrated into classroom practices. In this paper I explored how co-design and learner-centered design approaches can be combined with game-based mobile learning activities and how this informal approach, can lead to more formal educational opportunities. The game has gone through three different versions, the second and third taking place in local middle schools as part of special elective courses. Additionally, these design processes can provide additional insight and tools for the evaluation of mobile learning. I discussed how co-design practices have been the focus of current research efforts in the field of educational technologies but not as prevalent in mobile games to support learning. I presented how setting the focus on the entire experience of mobile game-based learning activities can provide richer opportunities for data collection and evaluation.

More than 75 young people aged 13-16 have played Skattjakt, and 22 students have been involved in the different workshops and classes where new games have been designed and played. Involving children in the design process of mobile games can give new perspectives regarding the nature of their learning practices while learning with these games. For this paper the goal was to discuss the value of co-design for the implementation of new mobile learning activities as one of the ways to analyze and understand the nature of these novel learning practices and outcomes.

From these nascent results I can see the promise of a co-design approach to alleviate some of the design challenges faced, such as designing activities that take advantage of mobility and context that have a value beyond traditional learning and begin to address some of the new ways young people utilize this technology. Skattjakt’s playful and game-based learning approach integrated with co-design can provide children with powerful opportunities not only to learn through experiences, but also to develop reflection skills by co-creating new games. Moreover, this provides relevant design input by the inclusion of students in the process, which provides an additional insight into the design and evaluation of novel learning processes with mobile technology. In general, I can reflect that in terms of innovation Skattjakt has gone from an informal activity involving researchers and after-school clubs to more formal settings of school-based activities involving teachers and students in designing and making new games. Recent developments in the project include one teacher from the local school designing the third version of the game together with the class that played the second version.
4.6 Summary

In this chapter I have presented two papers, a journal paper, and a book chapter that illustrate how my research has evolved from delivering content via services to mobile devices to investigating how context and collaboration can be used to design and develop learning activities that directly involve the learners from the onset. The work presented furthermore looks at the importance of human-centered design and methods that actively involve and give control to the learners in the process to create and expand artifacts. Table 2 illustrates the different research approaches used for each effort and how the design approach has shifted over time throughout the different projects along with the stakeholders.

<table>
<thead>
<tr>
<th>Research Approach</th>
<th>Paper I MUSIS</th>
<th>Paper II &amp; III AMULETS</th>
<th>Paper IV Skattjakt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods for: Data collection and evaluation</td>
<td>Surveys, Interviews, Observations</td>
<td>Surveys, Interviews, Observations, Video / Photography, Data Collection, Workshops</td>
<td>Surveys, Interviews, Observations, Video / Photography, Data Collection, Workshops, Paper Prototypes, Low Fidelity Prototypes, New Products created by Users</td>
</tr>
<tr>
<td>Design Approach</td>
<td>Professional</td>
<td>Participatory - Forest &amp; Town Square, Meta-Design - Teacher Students</td>
<td>Participatory - Version 1, Meta Design - Version 2 &amp; Version 3</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>Researchers, Teachers, Project Partners</td>
<td>Researchers, Teachers, Students</td>
<td>Researchers, Teachers, Students</td>
</tr>
</tbody>
</table>

Table 2 Mixed research approaches across the projects

Across the projects, the data collection for evaluation has evolved from standard descriptive ways to a more participatory approach that includes the users (learners) in the design process. This provided the opportunities to expand from workshops to actual artifact production and student ownership in order to foster innovation and adoption by the users, in this case teachers and students. This cyclic process of design, development and the real world can be seen as a direct outcome of the design-based research approach discussed in Chapter 3. The active involvement and the ability of learners to co-construct new materials is one of the main benefits of collaborative learning. In the next chapter I present the findings based on these papers and from these results identify design factors that support mobile collaborative learning.
5 Analysis of findings

In this section I discuss the main findings of my research. I start with a further elaboration of the ideas related to the collaboration in context framework presented in Chapter 2. These discussions are based on the work carried out in the three projects presented in the four papers. From the use of this framework and the empirical data collected during the different trials a number of factors for the design of mobile collaborative learning systems are identified. The section concludes with a discussion of the limitations of my research approach in terms of the generalizations and validity of the findings.

5.1 Collaboration in context

In the proposed framework discussed in Chapter 2, mobile collaboration in context is defined on the three axes of location, activity and social relations. Table 3 summarizes the main features of each project using the framework. This framework provides insights into the activities column. The middle column provides the location context for the different trials. The right column looks at communication and collaboration modes. Using this framework we can analyze the three projects summarized in the previous section to help identify the design factors for collaboration.

<table>
<thead>
<tr>
<th>context</th>
<th>activity</th>
<th>location</th>
<th>collaboration &amp; social relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUSIS &quot;Push content&quot;</td>
<td>support of educational activities</td>
<td>independent physical space</td>
<td>enhanced communication via technology</td>
</tr>
<tr>
<td>AMULETS &quot;Quiz like games&quot;</td>
<td>problem-solving via computer-supported mediation</td>
<td>co-located locations generally indoors and outdoors</td>
<td>promoting collaboration via technology</td>
</tr>
<tr>
<td>SKATTJAKT &quot;Puzzle games&quot;</td>
<td>team-based navigation and problem-solving</td>
<td>outside</td>
<td>Game-focused collaboration</td>
</tr>
</tbody>
</table>

Table 3 Projects and findings mapped on the context model

5.1.1. The MUSIS project

In the MUSIS project the main goal was to enhance and support communication, in contrast to collaboration between the students and the teacher. In addition, the project explored what new scenarios might emerge from the use of these services. In the second trial the social relations aspect was expanded by the creation of a multi-casting tool available on the phones that enabled students and teachers to send video messages from each group to everyone. Based on the findings from MUSIS across the context in collaboration framework, the project clearly illustrated that collaboration needs a means to happen. Just supplying a novel technology that simply enabled rich media communication did not enhance communication. Conventional means like e-
mail and web sites generally provided the students with the information and communication they needed. The mobile services were well received in the beginning but the interest diminished as the trials progressed (see Paper I). MUSIS clearly pinpoints the question of what are the benefits of mobile content delivery, and where and when should it be used.

5.1.2 The AMULETS Project

The overall goal of AMULETS was to explore how mobile technologies could support collaborative learning across locations. The trials were designed together with teachers, using the framework for conceptual development and evaluation. The activities were designed to foster collaboration face to face and across computer-mediated communication. The children participating explored different types of activities concerning media content creation, problem-solving through negotiation, navigation and the sharing of artifacts. The location was essential in the trials and provided different environments for collaboration to take place, including the forest, the city and the museum, the field and the lab. The social aspect of the framework was explored by the created activities and locations that required different types of collaboration.

The results from this work provided insights into how learners experienced the different activities as well as into the usability of the technical solutions implemented. This process was based on three different trials with an iterative design cycle, guided by the ideas of design-based research. In general, the outcomes of these trials indicate that children are open and positive when it comes to using mobile technology in everyday learning activities. From the results of the assessments, we experienced that children paid more attention to real-life situations than to computer-generated content and characters. The findings of AMULETS were analyzed, guided by the collaboration in context framework that supplied a means to assess the usefulness and to look at the learning processes based on the activities, the location and the social relations. In general, activities were expanded to investigate different collaboration techniques afforded by the mobile devices through creating activities that used text, camera and audio, based on the location that supported the regular curriculum of the classes or the university program. AMULETS provided different modes of collaboration between peers, the sharing of content, and joint problem-solving.

5.1.3 The SKATTJAKT project

Skattjakt’s implementation approach was from the beginning was focused on informal learning. The game conceptually started from the idea of using mobile games for supporting informal learning activities. We explored different design methods to implement these ideas. The location was determined by the involvement of the local orienteering club, and the activities combine physical activities, problem-solving and informal learning. The social aspect of collaboration was team-based and, as the project progressed, additional collaboration aspects were introduced and new game designs concepts developed by the co-design team.

Through the involvement of teachers and the outreach program of the club in local schools, several trials of Skattjakt were running during the spring of 2008 and future activities are planned for the coming fall. The social aspects were further investigated in the design process, and after the second trial the players worked on creating new games together, exploring how to enrich the game experience and the story. From the
researchers’ side we further developed tools that enabled geo-coded tagged photographs during gameplay for task and documentation purposes.

From the analysis of the activities and interviews with students and teachers, the combination of playing and creating new games provided enjoyable creative challenges for the students. The analysis of the results of the surveys conducted during from the first and second versions illustrate high levels of excitement and positive feelings about collaboration. The combination of designing new games and creating tasks for the players is something that the players say could be used in integrating different school subjects, such as physical education, environmental, math, and science studies (Spikol & Milrad, 2008). This process also helped the teachers see new ways in which they could begin to consider how mobile tools and systems could be integrated into their teaching based. Skattjakt has provided an insight into my research by enabling richer evaluation opportunities that can help the design of future mobile learning games and learning activities through this direct involvement by working with the learners and teachers in the creation of new learning materials. This is supported by the continued versions of the game being developed by local schools in June of 2008. The findings from this work provided grounds for further investigations that directly involve the players and teachers in the design of learning activities with mobile devices.

5.1.4 Summary
The findings from these projects point to the importance of having a human-centered and participatory design of mobile learning that takes into consideration the activities, the location and the social context for collaboration. The MUSIS project concentrated on the task without balancing the location or the social contexts for collaboration, resulting in mobile services that generally enriched one way communication but did not enhance collaboration. AMULETS used activities, locations and social context in the trials and utilized co-design with the teachers. However, the continued use of the artifacts and the system was limited. The focus on the different collaboration modes provided good results for using new technology but lacked in creating collaborative spaces for the students to explore. Skattjakt focused on informal learning and games combined with the co-design, and the other design methods provided activities, reasons for locations and the social issues for collaboration. Working directly with the students in the design of new games leads us to the next section, the role of the design in discovering the factors for collaboration.

5.2 Iterations and design time
The three projects used iterative cycles based on design-based research to guide the different efforts. The collaboration in context conceptual framework proposed that activity, location and social relations should be layered with the design model proposed by Fischer and Ostwald (2003) to help in identifying the factors as illustrated in Table 4.
The projects discussed illustrate in this chapter the shift from professional design to meta-design. MUSIS generally operated in professional design since the users did not have the option of design or use time with the service approach of the project. The students and the teachers created artifacts but the focus was on delivery. AMULETS began to provide more opportunities for design and use time with the teachers and the students, especially in design time, since the learning activities were developed with the teachers. Skattjak explored use time significantly through the creation of new games and the adoption by teachers and students.

### 5.3 Identification of design factors for collaboration

By comparing the design time to the proposed framework the design factors for collaboration can be identified across the projects, providing some generalizations from the research. I propose that **Creation, Action, Sharing** and **Reflection** are the design factors that should guide the design of mobile collaborative learning. They are derived from looking at mobile collaboration in context and the roles of the users in the different design approaches. Table 5 presents the attributes of creation, action, sharing and reflection with general examples from the empirical work based on the three projects. The aim of this thesis is to answer the main question presented in the introduction: Which are the most relevant factors that influence the design of mobile collaborative learning?
Table 5 Design factors for mobile collaborative learning

<table>
<thead>
<tr>
<th>Factors:</th>
<th>creation</th>
<th>action</th>
<th>sharing</th>
<th>reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>learners actively create artifacts and learning materials</td>
<td>learners explore physical and tangible data via the real world</td>
<td>learners share artifacts and converse about data</td>
<td>learners collaboratively create knowledge through reflection and conversation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examples:</th>
<th>AMULETS</th>
<th>AMULETS</th>
<th>MUSIS</th>
<th>AMULETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students take and exchange photographs to solve task</td>
<td>Students explore the forest, the city, and nature</td>
<td>Students share data between groups to organize the project</td>
<td>Students present results in post activities. Teacher students have a future design workshop</td>
<td></td>
</tr>
<tr>
<td>Using the GPS enabled camera phones that link the location of where the photograph was taken</td>
<td>The game like structure provides the opportunity for the learners to explore outside the walls of the classroom</td>
<td>The multicasting feature enables each learner to broadcast artifacts to their own group, the entire group, and to the teacher</td>
<td>The display of artifacts linked to specific locations on web based maps enabled reflection spaces to be created</td>
<td></td>
</tr>
<tr>
<td>Skattjakt</td>
<td>Students create new games and new students play these games</td>
<td>Skattjakt</td>
<td>AMULETS</td>
<td>Skattjakt</td>
</tr>
<tr>
<td>Students compete on a playing field</td>
<td>Students solve tasks by text</td>
<td>Students review game via map application. Students create new games</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skattjakt</td>
<td>Students use past game experiences as design base for new games</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Säljö (1999) presents one part of the answer to this by stating that learning takes place in the interplay between culture and individuals, and it implies the transformation of individuals and groups in terms of the nature of the tasks they master. He goes on to point out two different types of tools: the physical (or technical) and the psychological (or mental) tools that people rely on to acquire knowledge. Sfard (2008) expands Säljö’s interplay between the individual and the group. She uses the term *commognition*, a combination of *communication* and *cognition*, stressing that interpersonal communication and individual thinking are two facets of the same phenomenon. Sharing therefore can be seen as a social aspect of learning. The
potential of mobile learning is that it offers the opportunity to explore these two
different types of tools by changing the landscape of learning through enabling
learners to go outside of the classroom and to bring the outside world inside the
classroom (Hooft & Swan, 2007). In order to accomplish this more effectively some
additional factors need to be considered, and this is where **action, creation, sharing**
and **reflection** can be used as factors in the design of mobile activities. In the coming
sections I will expand these ideas to further illustrate the main contribution of my
research.

5.3.1 Action

**Action** is the first factor identified. Action is illustrated in both AMULETS and
Skattjakt with the use of situated learning by placing the users in the field to perform
tasks related to the environment and the learning domain. Action enables learners to
explore the physical world outside and inside across the learning environments.
Physical action can be used to visualize data in the real world, providing means for
bringing information into the classroom from the outside or sending it back out into
the world. These actions enable collaboration that provides the means for learners
to experience learning in and across different physical settings. Without being tethered
to the computer in the classroom students can be mobile, taking the tools with them as
they explore, while supporting collaboration across different places. At the same time
they can bring back material to be used and evolved in the classroom. In Figure 3
(page 10) action is clearly illustrated by the learner with a mobile device that is able
to interact and collaborate across different locations such as in school, at home, in
nature, and with sensors or devices like GPS. Learning can be described in the mobile
context as flowing across locations, times, topics and technologies (Sharples et al,
2008).

5.3.2 Creation

Creation is important because it enables the learners to produce artifacts but also to
own them for future use. This empowers the learners to become active in the
construction of artifacts. These activities provide opportunities for tangible and
valuable “meanings” happening in the learning process. Mobile technologies provide
a rich tool set for this creative endeavor, enabling collaborative work between
different locations. Photographs, video, audio, text, location and additional data from
geo-tagging photographs are just some of the tools presented in my work that mobile
and pervasive technologies have supplied. With mobile devices the artifacts created
can be collected, organized and shared on another scale with technology. Providing
tools for creation is a factor that needs to be considered in promoting and developing
playful learning. Fischer and Ostwald’s (2005) meta-design concept empowers
learners to construct personal meaning from the design process, and artifacts lead us
to the second factor, **creation**. Table 5 shows two examples from the empirical work
presented in the thesis. For AMULETS in the Växjö Square trial one of the activities
involved taking photographs with a mobile phone of the current town square. By
exchanging the photographs with the indoor team and communicating via text
messages in real time the two teams were able to locate between them where an
historic building once stood, creating a mental image of the town square and a digital
artifact for post-activity review. In the later versions of Skattjakt the students used the
game as a basis to first create new game concepts that were play-tested with paper
prototypes and with board games. In the latest version, the students created new
games that other students played.
5.3.3 Sharing

The creation of artifacts and physical action in the world maybe is not enough to support collaborative learning. Sharing enables these constructs by letting students work together on a peer-to-peer basis or with the involvement of a more capable mentor that guides the learning. Learning can be seen as enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs and other norms (Hoppe et al., 2005). Across the three projects presented in this thesis sharing has been a key activity. In the second trial of the MUSIS project that took place in 2007 the students shared ideas and concepts across the mobile devices, prototyping and developing their final projects with software tools. In AMULETS students shared tasks, artifacts and knowledge across locations and devices. For the Skattjakt projects students and teachers shared experiences of past games when they developed the successive versions for their games. The students worked in small teams together and at times with the guidance of teachers and researchers. Collaborative knowledge building requires reflection to construct the mental meanings needed for collaborative knowledge gain.

5.3.4 Reflection

Reflection together with other learners as facilitated by educators provides an important factor for design that has mainly been overlooked in mobile learning. The empirical efforts presented in my thesis have concentrated on creation and action. Through the introduction in the later trials of AMULETS and Skattjakt of presentations, design workshops and then game-making courses the students and the teachers began to reflect about how to use mobile learning when they started to design new mobile activities. Reflection is a key part to many learning approaches, especially in CSCL. Reflection allows the students to generate their own solution paths as well as helping to make them into conscious and creative members of the problem-solving community (Brown et al, 1989). In the AMULETS project reflection was the central component of the post activities of all three projects. The students in the pilot project created presentations about the forest as their final projects. In the Town Square project the students created mind maps during the activity and then made a newspaper about their journeys back in time. In Skattjakt, on the other hand, the students needed to reflect about the game in order to design the new games.

5.4 Summary of Findings

The use of mobile and pervasive technologies as described in this thesis contributes to a shift in the focus of interaction from a single screen in a stationary place to active interaction across different places. This shift provides some design challenges that require different design factors to be considered and that is where action, creation, sharing and reflection can be used to help design mobile systems and tools to support education. In contemporary learning theories it is currently accepted that most knowledge can be seen as an interpretation of personal experiences and that it is social in nature. Therefore, knowledge is jointly constructed in interactions with artifacts, discussions with other peers and reflections upon concepts in a specific domain (Duffy & Cunningham, 1996). The context of how people collaborate and with what tools, activities and locations plays an increasingly important role when mobile devices enter the learning arena. Playful and active learning provides a good case for how mobile learning can be used in education. Mobility offers the opportunity for students to get involved in activities that support experience and
inquiry. This is done through collaboration and the use of new technologies and software tools that can support a wide variety of cognitive and social skills, provided that the designers of systems consider how users can act, create, share and reflect the learning experience.
6 Conclusion

The activities and results presented in this thesis contribute to identifying novel design factors for supporting the design of mobile collaborative learning. Sharples et al. (2008) point out the need for a better definition of mobile learning that goes beyond the reliance on using handheld devices to just deliver content. Price et al. (2003) have, additionally, created new frameworks for modes of collaboration that go beyond the single screen in a classroom. The fact is that learners are in action, physically moving and actively creating, sharing and reflecting collaborative experiences. The results of the activities suggest that context and collaboration need to be addressed differently when developing software tools to support mobile learning activities. The results additionally point to the need to directly involve the students in the design process, thus connecting the learners to the iterative cycles of interaction design and research. The validity of the results in these design experiments is rightfully questioned; yet, throughout the work in participatory design, co-design and design-based research a lot of attention is focused on the role of researchers and teachers, while little is focused on the learner, which provides an opportunity for further work in this direction (Hoadley 2004, Spikol 2008). I believe that involving the learners in the design process can lead to promising results, as shown by some examples of work presented in this thesis, and offer ways to bridge the gap between everyday technology use and more formal learning.

In the cases presented and discussed in Chapters 4 and 5, aspects of co-design were used to involve first the teachers and then the students. As the cases progressed and it became obvious through evaluation cycles that involving the learners as stakeholders yielded additional benefits. This was especially apparent in the Skattjakt project, where through successive iterations by a local school in a collaborative class students and teachers developed version 3.0 of the game in an independent fashion, which hints at an adopted educational innovation. I believe this a relevant example of “meta–design” where the users have taken over the job of designer, have obtained real ownership of the artifacts and are creating new learning activities. The students from the school played this new game in June 2008. Recognizing these factors of action, creation, sharing and reflection when designing collaborative mobile learning provides key design criteria for understanding the context framework of activity and location and the social relations that take place in collaboration. Without the factors the learners’ needs are not the key focus for the design, and the products may result mainly in media consumption and instruction.

6.1 Lessons learned

Through the projects and by analyzing the key findings in chapter 5 I have identified some key lessons learned about mobile CSCL as listed below:

- Providing mobile services does not equal collaboration
- Supplying accessible tools enables creation
- Owning artifacts can improve motivation and learning
- Devising better evaluation methods promotes mobile learning

Researching in the domain of informatics and computer science provides a technology-driven research environment. The downside is that at times the services
developed are not necessarily focused on peoples’ need. Through the work in this thesis I have come to see that there is a gap between what researchers perceive as needs in the learning environments and what people need to support intellectual activities.

With the research presented in the thesis the goal was to work in real-world settings and expose teachers, students and organizations to the potential benefits of mobile technologies. In most cases some success was achieved. The independent ongoing work carried out by teachers and students in Skattjakt is a good example, where local schools together with an orienteering club are continuing to develop new games directly with teachers and students. In future work, my goal will be to provide tools and support materials that can be easily integrated into everyday practice. The challenge is to create tools that enable teachers and students to create learning materials on an everyday basis. The cases presented in this thesis, like much research, only provided limited innovation for the learners. Skattjakt is the exception and, as noted, continues, but with primitive tools. This does reiterate the issue of a gap between research goals and the reality of practice. The design method and evaluation of collaborative mobile learning activities present many challenges. Some of them, as I suggested, can be approached with direct learner involvement in the process, but this approach makes evaluation more complex. A larger question is what to evaluate from the standpoint of my research, in which learning traces (Järvelä, 2006) and triangulation (Yin 2003, Denscombe 2007) point towards more rigorous evaluation methods that supply more structure for mixed approaches.

6.2 Limitations

The overall research discussed in this thesis form a solid foundation for continuing to research these factors to understand how to design for collaborative mobile learning. The design-based research approach provides opportunities to investigate phenomena in real-world settings, and it affords the ability to evolve the experiments to meet the demands of the users and the researchers to create innovation and expand theory. This approach has it limitations in terms of validity by having a loose structure for the methodological approach, but despite what it may lack in scientific rigor at the moment it has provided a good platform to create solid pilot studies that have identified novel factors which now need a more thorough investigation.

6.3 Future efforts

The factors identified in this work, Action, Creation, Sharing and Reflection and the framework of activity, location and social context provide an initial platform that can aid in developing future guidelines for the design of collaborative mobile learning. This effort will require a stronger theoretical foundation in CSCL and learning technologies that address how people collaboratively learn with technologies across new learning ecologies. From a design-based research perspective (and that of the other design processes) an investigation and literature review of projects where learners are involved is warranted.

The pervasive and mobile technologies discussed in this thesis can together with more elaborate methods provide additional techniques for evaluation. The future efforts mentioned above will also require a better design of experiments that will need to give learners more opportunities to have ownership and control of the work they create, supporting the action required to collaborate, and the tools to reflect and gain
knowledge for collaboration. The benefits, in the author’s opinion, of utilizing these factors in the design of collaborative mobile learning will be the identification of needs for future design guidelines. There is a need for designers and software developers to have a toolkit for supporting mobile collaborative learning activities that take into consideration action, creation, sharing and reflection.
References


Collection of Papers

Paper I

Paper II

Paper III

Paper IV
Paper I
Anytime, Anywhere Learning Supported by Smart Phones: Experiences and Results from the MUSIS Project

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ABSTRACT
In this paper we report the results of our on-going activities regarding the use of smart phones and mobile services in university classrooms. The purpose of these trials was to explore and identify which content and services could be delivered to the smart phones in order to support learning and communication in the context of university studies. The activities were conducted within the MUSIS (Multicasting Services and Information in Sweden) project where more than 60 students from different courses at Växjö University (VXU) and Blekinge Institute of Technology (BTH) participated during the course of their studies. Generally, the services integrated transparently into students’ previous experience with mobile phones. Students generally perceived the services as useful to learning; interestingly, attitudes were more positive if the instructor adapted pedagogical style and instructional material to take advantage of the distinctive capabilities of multicasting. To illustrate, we describe a number of educational mobile services we have designed and implemented at VXU and BTH. We conclude with a discussion and recommendations for increasing the potential for successful implementation of multicasting mobile services in higher education, including the importance of usability, institutional support, and tailored educational content.

Keywords
Ubiquitous Learning, Educational Mobile Services, Smart Phones.

Introduction
In the past decade, the Internet has spawned many innovations and services that stem from its interactive character. The emergence of ubiquitous and inexpensive microprocessors and wireless networks has lead to the wide deployment of mobile devices that allow us to access and to handle information almost anytime and anywhere (Roussos et al., 2005). Diverse multimedia applications have flourished with recent advances in hardware and network technology with the proliferation of inexpensive video-capture devices and widespread adoption of the worldwide web via these mobile devices. All these forms of interactive multimedia and communication offer new possibilities for supporting innovative ways of learning, collaborating and communicating (Milrad, 2003; Thornton & Houser, 2004). These technologies and new forms of mobile communication and collaboration have been widely adopted by young people and integrated into their everyday lives. Clear indications of this trend can be found in sites such as www.youtube.com, www.flickr.com, and www.facebook.com. However, this transformation does not live up to the promises and expectations when it comes to the use of mobile technologies at schools and universities (Norris et al., 2002; Tatar et al., 2003).

Lanksheer and Knoble (2006) claim that formal education ignores some of these trends and argue that mobile and wireless technologies and new media might be integrated into current school educational activities, as they are transforming and defining new literacies in teaching and learning. Thus, there are a number of challenging questions that deserve further exploration. What are the implications of using mobile computing and wireless communication for supporting learning and teaching? What new scenarios and applications will emerge? In order to understand the possible impact of using smart phones for facilitating learning and teaching, we will proceed by presenting the results of one of our on-going projects, MUSIS (MUlticasting Services and Information in Sweden).

This paper presents the results of two pilots studies conducted within the framework of the MUSIS project between the periods of 2005 and 2007. By presenting these two periods of the trials, we hope to gain new insights regarding how attitudes and expectations towards using mobile phones in educational settings may have changed over the last two years. The next section describes the MUSIS project and the technical infrastructure. The method section describes the implementation of the trials and the data collection techniques we have used. The results and discussion section describes the outcome of our trials and explain how students experienced the mobile services. Issues and
problems are discussed with regard to the technology and its use. Overall conclusions are provided in the final section of the paper.

A brief overview of the MUSIS project

The main objectives of the MUSIS projects are to explore, identify and develop a number of innovative multicast mobile services to support learning with multimedia information to be distributed over wireless networks using multicasting solutions at university. The project has had two pilot phases, the first one during 2005 and the second in 2007. MUSIS (http://www.musis.se) has brought together different partners. The key partners have been TeliaSonera (TS), Sweden's largest telecom operator, the City of Stockholm, Växjö University (VXU), and Bamboo MediaCasting, a company pioneering in the field of cellular multicasting. Also, Luleå Technology University (LTU), the Royal Institute of Technology (KTH) in Stockholm and the Blekinge Institute of Technology (BTH) have been actively involved in the project.

Multicasting mobile services developed in the MUSIS projects are organized as a range of content channels to which users can subscribe. Each user can build a personal portfolio of channels that interest them. Multimedia content is sent, according to a predefined time schedule, to subscribers over the GPRS (General Packet Radio Service) network using wireless multicast technology (Varshney, 2002). It is also possible to program the MUSIS system in order to send content to the phones based on discrete events. The content sent to the phone is downloaded in the background and stored on the phone’s memory card. Once the content has arrived, the phone beeps announcing a new message has been received, similar to standard message services. Users can then interact with the MUSIS client installed in the smart phone in order to view and save the content. This approach differs from the latest type mobile services offered by the telecom industries, which are using streaming technology. The digital content used in these trials included TV news, music, entertainment videos, general information related to student’s activities, such as lecture notes (including video and audio), and specific information related to the different courses.

During the second phase of the project, we introduced additional content tools for the users allowing them to multicast video, audio, images, and text directly from the handset. We also expanded the web interface that controlled the subscriptions to include the ability to upload and convert content for multicast delivery. This fundamental change in this trial focused on shifting the traditional broadcast model we used in phase 1 of the project from a one to many model, to a many-to-many model, thus providing students with the ability to explore how these concepts could be used in an educational environment. The content in this phase was created by the students and the instructors and it included text, calendar events, photographs, and video. All these materials were sent between the students’ groups and back and forth between the instructors and the students.

Technical aspects

A complex technical infrastructure has been developed in order to deliver the different mobile services to the students. This task requires complex software solutions in order to connect and combine the content coming from different content providers. Figure 1 illustrates the generic technical architecture and the different hardware and software components used in the project.

Bamboo’s equipment provides the multicasting feature in the GPRS network. The content management system (CMS) located at TS is responsible for scheduling the content transmissions. The MUSIS CCS (Collect, Convert and Send) developed and implemented at VXU is responsible for collecting, organizing, and converting the different digital material coming from all content providers (including educational material produced by the teachers) as described above. The MUSIS CCS system provides tools to manipulate content automatically and transmit it to Bamboo's router for distributing to the users. The CCS can get the content from the content's resources based on pre-defined rules, convert it to formats that are supported by the mobile handset and transmit it to Bamboo's server. These activities can be done automatically without human intervention.

The following illustration (see figure 2) describes the generic architecture of the MUSIS CCS system. As seen in the illustration below, the system is based on several different inputs and outputs. The system, which has been implemented using Java related technologies, is scaleable and it consists of modular, reusable and easily expandable
components to be able to deal with new types of content. This includes all features, i.e. the collecting, converting and the sending mechanisms. The system is programmed in Java using JSP and Java Beans on a Linux platform. It also uses open-source tools and applications.

Figure 1. MUSIS generic architecture

Figure 2. Generic illustration of the CCS system (Collect, Convert and Send)
In the next section we concentrate on those activities carried out at Växjö University and Blekinge Institute of Technology. We present the results of a couple of pilot studies conducted over a two years period, focusing specifically on the question of whether students would find a mobile phone useful for supporting their learning, and in particular whether multicasting mobile services would be suitable for supporting learning and other activities related to their academic life. These studies aimed to look at the patterns of use of the various mobile services and the impact on students’ learning habits. We were also interested in determining what type of functionality is required for educational mobile services to be considered useful. Our results lead us to advocate a comprehensive approach regarding the introduction of smart phones and mobile services in university classes that considers not only technical features but also the individual, social and organizational aspects of technology adoption.

**Method**

**Participants**

For the first set of trials, we solicited volunteers from students enrolled in two courses offered at VXU during the spring term of 2005. One course was offered at the School of Humanities, and the other at the School of Mathematics and Systems Engineering. After a short presentation delivered by members of the research team at the beginning of the term, students from these two courses volunteered to participate in the pilot. Twenty-two students from the course in the School of Humanities and nineteen from the School of Mathematics and Systems Engineering volunteered. Each volunteer was given a "smart phone" for the duration of the school term (3 months). Although the number of smart phones available limited the number of participants, we were able to provide phones to all students who wanted to volunteer as participants. Each student signed a contract of use that specified their obligation to participate in the project in return for free use of the phone and a small amount of money they could use to make phone calls. The project also provided continuously available online and face-to-face support. The project began with a workshop session to familiarize the students with the smart phone and the software. Participants ranged from 19 to 40 years of age, with a mean age of 26. Nineteen were female and twenty-two male. All 41 students already owned at least one mobile phone at the start of project. With regard to the issue of how much they spent on their own phone services before joining the project, on average a student in this group paid 28 USD a month. Twenty per cent of the 41 students participating in this study spent more than 45 USD a month.

For the second trial, we worked with BTH students during the spring term of 2007 in a special project course in the Literature Culture and Digital Media in the Humanities program (END011). Twenty-one students and two instructors participated in the trial over a five weeks period. Participants ranged from 20 to 26 years of age, with a mean age of 24. Eleven were female and ten male. The students organized themselves into five groups consisting of 4 persons each. The expected outcome of the course for the students was to produce 5 pilot mobile applications that will help tourists to explore the history of the local city in novel ways using mobile phones and interactive storytelling techniques. The students in this trial all owned at least 1 mobile phone and spent a similar amount in phone costs compared to the 2005 trial.

**Equipment and Services**

The participants of the studies were each equipped with smart phones. For the first trail the students were supplied with NOKIA 6630 phones and for the second trial NOKIA N70 phones were used. Both phone models run on Symbian based operating systems and have mobile internet browsers, cameras with digital zoom, video, still, and audio recording, and RealOne’s player for playback and streaming of 3GPP-compatible and RealMedia video clips. Additional applications include a personal information management (PIM), a calendar, and a contacts database. Users could synchronize contacts and calendar stored on the phone with data stored on a personal computer. Since the Symbian operating system is open we were able to develop a Python application that enables mobile multicasting from the handset. This particular feature was implemented during the second trial.

Technical development of MUSIS services took place concurrently in both studies, enabling refinements during the project cycles. For the first pilot phase that took place during the period March 1st- April 30th 2005, all participants accessed the same set of channels, receiving approximately 5 to 7 MUSIS messages (push technology) daily. One of these channels carried educational content related to their VXU course. Subscription to the educational channel was
compulsory throughout the project. However, beginning May 1, 2005 users were able to subscribe to up to 30 channels of their choice using a Web interface (both available via a PC or a mobile phone) specially developed for this project. During the second phase that took place during April 1 to May 24, 2007 all participants and two instructors accessed two public channels and then each of the five groups had a group channel for inter-group communication. In this paper, we focus specifically on our experience and results with the different educational channels only.

![Figure 3. The MUSIS client interface (left) and the mobile multicast client interface (right).](image)

**Implementation of phase 1**

For the first trial, educational materials delivered for this project include small “micro lectures” in video format, voice based course information and assignments, and specific information related to the logistics (calendar information, cancellation of lectures and so on) of the different courses. In the case of the “micro lectures” the audio based and text information, the contents were developed for (and sometimes tailored to) the phone by the course instructor. In order to send this material to the phones, the teacher used a special web interface we designed for this purpose. We also developed a number of solutions that allow internet-based educational resources used in the course to be sent automatically to the phones. Instructors were also given a smart phone of the same type given to the students.

FirstClass (FC) is a communication platform used at Växjö University mainly for distance education but also for campus based courses. There are two ways of accessing the FirstClass application. Students can use the FC client software or a web-based client directly from any browser. In the current version implemented at VXU, the only way to deliver FC content to mobile phones is by purchasing a very expensive SMS module. We developed an application using java and XML that it is used to convert the instructor's contributions in the FC forum to an RSS (Real Simple Syndication, an XML format for syndicating web content) feed that it is then multicast to the phones. The java application was running in the background of the FC forum, so the instructor’s contributions to the forum were automatically transformed to a format suitable for the phone. The content from the FC forum arrives to the phones as a file in HTML format that can be viewed with the phone’s Internet browser.

**Implementation of phase 2**

In the second trial, the MUSIS system was used to foster collaboration and communication between the instructors and the students. Figure 4 below illustrates how communication and collaboration between the teachers and the student groups was envisioned. Instructors and students could multicast to group members, the entire class, specific groups and instructors using the mobile application we developed for the handset, as well as the development of the web-based interface to achieve the same goals. The system and the smart phones supported group and class interaction. This allowed the students to schedule group work and giving the instructors an additional way to give feedback using video, audio, and text messages to the class and the students' groups. This also provided ways to coordinate and organize the class work with calendar and text based messages sent to the phones.
In this second phase, we modified the multicast model to allow any user at anytime and from anywhere to multicast content from the smart phone. This fact opened up different ways to use the technology not only in educational contexts but also to support students’ daily activities. The key application that enabled this feature was a python application we developed enabling digital content generated with the smart phones (including video, still photographs, and audio) to be uploaded to the system and then multicast as an event to a particular channel. In addition, the application also provided plain text and calendar events that could be multicast.

**Data collection across both projects**

Given the exploratory nature of these studies, we used multiple methods to collect data for both phases of the MUSIS project. This allowed us to scan the patterns of uses and attitudes that could be investigated more specifically in future studies. For the first phase participants completed web based questionnaires in weeks 1, 5, and 10 of the project. The first survey included items that measured personal attitudes toward mobility, attitudes toward media formats, and how much different media formats were used. The second and third surveys included items regarding perceived effect of the phones on learning, preference for different media formats, preference for channels, and perceptions of telephone functionality and usability. Additionally, members of the research team facilitated four focus group interviews with 15 participants, which were videotaped.

The focus group ranged in size from 3 to 6 participants. The interview covered issues regarding the participants' perception of the project in connection to the services, the functionality and usefulness. Additionally, the participants were asked to suggest and discuss additional educational mobile services that could be developed. Finally, a 90 minutes workshop with the students was held at the end of the term, which was videotaped. The purpose of these sessions was to carry out an open discussion with most of the students in order get an overall view of how the students experienced the project. In the second phase of the project we continued using multiple methods to for data collection. Focus groups sessions with each of the groups were videotaped, covering perception and future uses of the technology. Additionally, the communication data was collected providing some additional insight on how collaboration and communication in each group and how the mobile application supported this. The main objectives of all these activities were to assess the usefulness and quality of the services, to identify problems experienced by the students and to explore how future MUSIS services could look like.

**Results and discussion**

**General use and attitudes**

The majority of the students participating in the two MUSIS pilots had mobile phones of their own before they joined the project. Therefore, delivering content directly to the smart phones is transparent for them, integrating not
only with their existing day-to-day practices, but also with their views of mobility and accessibility as central to their life-style. It is important to note that even if their personal handsets supported a variety of features such as e-mailing, surfing the Internet, calendar support, and so forth, most participants used their phones only for making ordinary voice calls or for receiving/sending SMS. During the course of the first trial, students’ attitudes toward the services improved when they could for instance start choosing the channels of their preference and explore cost free the additional services. Through out both trials time periods the students perceived the MUSIS mobile services as something potentially useful, dynamic and as something that could be integrated in their every-day life.

Did students find mobile phones and multicasting useful for supporting their learning?

In the first set of trials, the participants were more likely to see the multicasting service as useful the more it was integrated into their course content. The cases presented in this paper differed substantially in how the instructors and the students used the technology. In the earlier trials, one instructor (for MEA708, in the School of Mathematics and Engineering) did not adapt his assignments or activities for the technology. The other instructor (for GIX 131, in the School of Humanities), actively produced content for this new medium. In addition to sending a relatively high number of MUSIS messages (41) to students, 7 were multimedia in form (video and audio).

### Table 1. Perceived usefulness of the educational mobile services after 5 weeks (n=41) and 10 weeks (n=41)

<table>
<thead>
<tr>
<th>Course</th>
<th>Week</th>
<th>Very useful</th>
<th>Useful</th>
<th>Fairly Useful</th>
<th>Not Useful</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIX131</td>
<td>5</td>
<td>27.3%</td>
<td>45.5%</td>
<td>18.2%</td>
<td>9%</td>
</tr>
<tr>
<td>MEA708</td>
<td>5</td>
<td>10.5%</td>
<td>52.6%</td>
<td>21.1%</td>
<td>15.8%</td>
</tr>
<tr>
<td>GIX131</td>
<td>10</td>
<td>40%</td>
<td>26.7%</td>
<td>20%</td>
<td>13.3%</td>
</tr>
<tr>
<td>MEA708</td>
<td>10</td>
<td>5.9%</td>
<td>35.3%</td>
<td>41.2%</td>
<td>17.6%</td>
</tr>
</tbody>
</table>

The importance of integrating the service into the pedagogy or instructional style of the course is illustrated in Table 1, which reports results from the survey item, “How useful did you experience the course related information sent to the educational channel”. In both classes, the majority of students saw the educational multicast services as useful or very useful in week 5. However, by week 10, that figure had dropped to less than 50% for MEA708. At the same time, the number of students in GIX131 viewing the services as “very useful” grew substantially.

In the most recent trial conducted at BTH (END011), the initial thoughts of how to use the system between the students and the instructors differed. The students expressed interest in using the system for communication and relevant school information while the instructors’ concerns were on supplementing the student feedback with the technology. While the student groups sent 24 messages where 10 of them concerned specific project work scheduling and the remaining where more social. The instructors sent a high number of messages (25) where 12 were video feedback to the different groups about ongoing work and the remaining organizational about course times and deadlines. Table 2 illustrates how the perceptions changed as the system was used during the trial. Over the 5-weeks trial period, the students’ perceptions changed, team communication was used and perceived as being helpful and very helpful. The instructor’s feedback over the trial period was evaluated as being not helpful by more then a third of the students, while slightly less then a third felt more positive about the feedback and the remaining undecided. The analysis of these results gives us the opportunity to think about further research issues regarding how to best provide feedback with mobile devices in future trials.

### Table 2. Perceived usefulness of the educational mobile services for the END 011 course after 5 weeks (n=21)

<table>
<thead>
<tr>
<th>Initial Perceptions</th>
<th>Week</th>
<th>No interest</th>
<th>Low interested</th>
<th>Interested</th>
<th>High Interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Communication</td>
<td>1</td>
<td>0.0%</td>
<td>19.0%</td>
<td>28.6%</td>
<td>52.4%</td>
</tr>
<tr>
<td>Instructor Feedback</td>
<td>1</td>
<td>19.0%</td>
<td>33.3%</td>
<td>28.6%</td>
<td>19.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Final Perceptions</th>
<th>Week</th>
<th>Not helpful</th>
<th>Helpful</th>
<th>Very helpful</th>
<th>Undecided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Communication</td>
<td>5</td>
<td>17.0%</td>
<td>21.0%</td>
<td>43.0%</td>
<td>19.0%</td>
</tr>
<tr>
<td>Instructor Feedback</td>
<td>5</td>
<td>38.0%</td>
<td>5.0%</td>
<td>24.0%</td>
<td>33.0%</td>
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With regard to usability and functionality of the phone itself, participants reported dissatisfaction with the small size of the mobile phone buttons, the quality of video, the small screen size, and the limited battery life of devices.

Discussion

These two trials clearly illustrate that both, students and teachers are open and intrigued while using everyday mobile communication and collaboration tools in education. What is still lacking is an understanding of how these tools provide new collaboration modes and how self-organizing environments can provide educational benefits (Dron, 2007). The perceived needs of the instructors and students remain unsynchronized with the instructors’ desire to use the smart phones for providing feedback to the students while the students prefer more logistical and practical information to be delivered to the handsets. The creation of rich media like audio and video generated by the students requires more efforts than the traditional use of SMS and chat. From this perspective, having students working and communicating using these new media types may have some impact on the different educational activities (Lai & Wu, 2006).

An unexpected finding took place in both trials based on the outcomes generated from the assignments developed by the instructor in the earlier pilot, and then again in the most recent trial regarding the use of the mobile application for many-to-many multicasting. Contrary to email, SMS, chat and other type of more instantaneous communication, students and instructors spent significant time staging and composing their answers and feedback, often recording multiple “takes” before the final video or audio was sent in to be multicasted. This suggests that a common practice of “composing” text messages may extend to audio and video messaging as well. Indeed, preliminary analysis of these recordings shows that the users tried to compress information not by indistinct, fast talk (similar to the abbreviations of SMS), but by concentrated, effectively expressed sentences.

Conclusions and future development

These studies were designed to explore the patterns of use of a number of mobile services experienced by students at a couple of university campuses and other locations of their choice. In the second trial these patterns of use were extended to provide the individuals the ability to multicast to the channels of their choice and to explore new patterns of collaboration. Impact on learning itself was not measured, nor would it have been possible to measure it meaningfully when the devices were used for such diverse purposes. Phone-optimized content was heavily used, and there was a clear request from the students that more resources be made available in this format, including administrative information from the universities. It is also important to recognize the need to address the technical requirements of producing and sharing of content across multiple types of devices and networks. This clearly points towards a low barrier for adoption of these mobile services by students in the near future if the ease of use between smart phones and traditional e-learning materials can effectively harnessed in ways that make sense and provided that the cost is comparable to wireless broadband.

Ownership of the technology is clearly important. As long as the phones are loaned, students are reluctant to invest time and money in personalization. This will prevent better evaluation of the impact of technology on learning. Greater institutional support is needed in order for the smart phones to be used more fully. Regular updates of timetables and content, as well as adequate training and hardware provision are needed. As more students bring the technology with them to the university, change will most likely be driven by their demands as learners.

Our results confirm the importance of designing applications and services for learners that are easy to use “on the road” that could be completed in short bursts of time (Wuthrich et al., 2003). Multicasting is one way to support what Brodersen, et al. (2005) call, “nomadic learners” who are more project oriented and who send much of their daily life, “transit between many physical places (“oasis”) such as classrooms, labs, workshops, libraries, museums, the city, nature, clubs and at home” (p. 298). However, our results also suggest that in higher education, a challenge is on designing for social technologies that allow for bridging different pedagogic goals (control of learning) and ways of communication between the different actors in the learning environment. These latest aspects require more than designing just services to connect people and content (Dron, 2007), but also creating new didactic sequences and educational activities that can connect formal and informal learning settings.
As our work continues, we will try to enhance the educational aspects of the mobile services by developing and implementing various solutions to specific problems we have identified based on our observations and the data we have collected from the students. Our future efforts will continue to refine both the technology and activities for providing learners with more meaningful experiences with regard to the use of smart phones in educational settings by providing more tools for collaboration that take in consideration of the needs of both instructors and students. Coming research activities include the continuation of our efforts within the framework of a new international project exploring the use of mobile devices for game based learning and field studies in natural science, math, and physical fitness supported by mobile applications.

Acknowledgement

MUSIS is partially funded by governmental bodies – Sweden’s VINNOVA and Israel’s MATIMOP - as part of the SIBED program, a joint Swedish-Israeli mobile technology research effort.

References


Paper II
Designing Innovative Learning Activities Using Ubiquitous Computing

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Abstract

In this paper we present our pedagogical and technological approach for supporting the design of novel situated learning activities that can be conducted both, outside the school and in the classroom. One main goal is to enhance the content of the curricula by bringing multimedia resources and mobile support to outdoor settings thus enriching the field experience. In order to illustrate these ideas we describe the outcomes of a trial we have conducted with thirty elementary school children. Moreover, we present the ubiquitous computing solutions we developed in order to support learning activities in the field of history. The results of our experiments indicate that children enjoyed learning in these kinds of environments where mobile devices are used in situ, thus supporting the learning activities in the context of which they are taking place.

1. Introduction

Situated learning [1] is a general theory of knowledge acquisition that is based on the notion that learning (stable, persisting changes in knowledge, skills and behaviour) occurs in the context of activities. Research increasingly indicates that the inability of students to apply concepts learned in formal contexts is in many cases due to the abstraction and decontextualization of learning [2]. But, it is not the abstraction of knowledge as such that distracts learners, but that the abstractions are not illustrated with examples in context. Context provides a framework that guides and supports the learner. Situated cognition argues that learning is simplified by embedding concepts in the context in which they will be used [2]. Situated cognition argues that learners must engage in authentic tasks as well.

Designing interactive learning environments (ILEs) to support situated learning is a challenging task, since in many cases the use of information technology tends to shift the learning environment to a more computer based representation, thus moving a step away from the core ideas of situated learning [3]. This latest view on technology-enhanced learning supported by wireless technologies and ubiquitous computing is referred to ubiquitous learning [4]. Ubiquitous computing also provides new possibilities for designing innovative educational activities that can be carried out both indoors and outdoors. The design of such activities is a challenge, especially in conceptualizing how these technologies can be used to support collaborative knowledge building in indoor and outdoor settings. Therefore, in the context of our efforts one main research question can be identified: How can challenging learning activities that support the notion of situated learning be designed using ubiquitous computing?

In this paper we present our on-going efforts connected to our AMULETS (Advanced Mobile and Ubiquitous Learning Environments for Teachers and Students) project. The paper is structured as follows; in section two we discuss those ideas related to design-based research as this approach guides our design ideas while in section three we present an educational scenario that integrates novel learning activities conducted with an elementary school classroom and supported by ubiquitous computing. In section four we present the assessment of these activities based on data we collected from our interactions with the children and the teachers. Section five concludes this paper by providing some conclusions and directions of future work.

2. Design-Based Research and Innovative Learning Activities

Design-based research is an attempt to combine the intentional design of interactive learning environments with the empirical exploration of our understanding of those environments and how they interact with individuals [5]. A recent view regarding the design of ILEs is presented by the Design-Based Research Collective group [6] who argue that design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice. Based on those claims, design is central in efforts to foster learning, create relevant knowledge, and advance theories of learning and teaching in complex settings. According to Edelson [7], the emerging design-based research paradigm treats design as a strategy for
developing and refining theories. Design-based research follows an iterative cycle of designing, implementing, analyzing and modifying. The research efforts to be presented in the coming sections were conceived and implemented inspired by the ideas and rationale suggested by this methodology. In our particular efforts, the educational scenario we developed was created based on prior cognitive, educational and technological research, relevant learning goals and content pedagogy, and knowledge of the specific educational context.

Design studies are typically conceived as test-beds for innovation. One of the main objectives is to investigate the possibilities for educational improvement by stimulating new forms of learning in order to study them. We consider our efforts as being an attempt to create innovative socially-situated exploratory learning experiences threads throughout elaborated learning sequences supported by ubiquitous technologies. Within the context of our efforts, the notion of socially-situated extends to the idea of learning activities guided by the context in which they are taking place. Based on these guidelines we designed a set of educational activities that was conducted in indoors and outdoors settings. These activities were designed having in mind the notion of situated learning practices.

3. Scenario Design and Implementation

In this section we describe one particular example that describes how we used ubiquitous computing and mobile technologies for designing innovative learning experiences that took place in a variety of outdoor (main square and city center) and indoor settings (in this case a museum). We describe all those aspects related to design, technology and pedagogy in connection to this particular activity.

3.1 Settings of the Trial

Twenty-nine 5th grade children (11-12 years old) participated in this trial that was conducted during the fall 2006. The content explored in this activity was related to the field of local history, which is part of the school curriculum. The physical settings where the trial took place were the main square and the museum of history in the city of Växjö, Sweden. The children were divided in three groups, each group consisting of ten students. Additionally, each group was divided in two subgroups of five children each, where one subgroup was working indoors in the museum while the other group was outdoors. The outdoors subgroups were supervised by several teacher candidates from our university. The overall activity was divided into three sessions over two days.

The outdoor subgroup was equipped with four smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding visual semacodes Tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. While the outdoor subgroup was in the field, the indoor subgroup was in the museum. In order to successful accomplish all the educational tasks the subgroups needed to collaborate using mobile technologies in a variety of ways.

3.2 Learning Activities

Together with teachers from one of our local schools, we developed a set of activities to foster collaboration between the subgroups participating in this trial. We decided to carry out this activity in the form of a collaborative game that has been organized as a set of missions that took place in different locations and across different time periods. The activities were designed containing challenges to be solved by the children in which they needed to collaborate and to apply problem-solving strategies. The game started when the field group scanned the “StartGame” semacode and a short movie was delivered to the groups’ mobile phones containing instructions from a set of three animated guides about how to proceed. The indoor subgroup task was to visualize the activity flow in the form of a mind map as the missions unfolded. The outdoor subgroup first task was to scan the semacode tag in the square. Once this was accomplished both subgroups received instructions about the first mission (see figure 1).

The outdoor subgroup needed to identify the building in the square that had Roman numerals while the indoor subgroup got instructions about how to decipher them. The task in this stage was to identify the year written in Roman numerals in the building in the main square. The collaboration started when the outdoor subgroup sent the picture of Roman numerals to the indoor subgroup (see figure 2). The discussion and argumentation about deciphering the roman number has been carried through mobile instant messaging (IM).

After the children decided which was the correct answer for the Roman numerals task, the outdoor subgroup scanned the correct semacode and the second

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1 Is a 2D barcode tag for embedding URLs to a specific location (source: http://www.semacode.org/). Semacode tags can be read by a camera-enabled mobile phone.
mission started. The goal of this mission was connected to mid 20th century history. The outdoor subgroup received in their mobile phone an audio file from 1939 while their task was to identify what happened on this day, the start of World War II. For the indoor group the task was to identify an audio segment of a poem from a famous Swedish poet from the same time. The indoor group had Internet access for help concerning their task and to support the outdoor group.

3.3 Pedagogical Aspects
One of the main pedagogical challenges of this game-based activity was to design learning tasks that fostered children’s collaborative problem solving skills within the same subgroup and with their peers. In order to add more realism to the game an adult performing as a blacksmith from past centuries provided some historical background, enabling the children in the square to share this information with those at the museum using pictures, thus giving a new contextual dimension to this information.

During the different stages of these trials, children needed also to use their mathematical (number conversion/decoding), historical (state of main square through history), and geographical/navigational (self navigation and historical map reading) skills. Strong negotiation skills were needed for the successful accomplishment of the tasks that were part of the quest. In addition, group discussions and interactions, as well as collaboration were also activities that enriched the learning experience. The integration of all these different features into a realistic scenario offered children a challenging learning environment.

3.4 Technical Aspects and Implementation
In order to provide technological support for the activities described in the section above, we developed and implemented several solutions that are illustrated in figure 4. The activities for the outdoor subgroup in the mobile environment (see left side of figure 4) were supported by 4 smart phones used as tools for collaboration, communication and for creating and receiving content. The first smartphone has been utilized to support communication between the subgroups using a mobile instant messaging application. The second smartphone has been used as semacode reader. The semacode application running in the phone served for reading the semacode tags and for triggering the events (based on a specific location) and actions to be conducted by the outdoor subgroup. The third smartphone was used as a mobile server for coordination of the other phones and the generated content. The last smartphone was used as a device for generating content related to the specific tasks and activities that the children needed to perform. In the mobile environment, two of the smartphones were running the Nokia Raccoon software that enables mobile communication via instant messages. The mobile phone leveled with the number 1 in figure 4 (running the first instance of Nokia Raccoon) was used for mobile instant text messaging.

The mobile phone leveled with the number 2 in figure 4 (running the second instance of Nokia Raccoon) was held...
by the adult supervising the children, and it was used to link the photos taken by a particular subgroup to the correspondent group activity. This specific group number was automatically added (in the form of metadata) to the photos taking by the children. This action was performed using a python application we developed. This feature was enabled with PHP-scripts on the server to keep track of all the communication that happened during the trial. All the content generated by the children contained contextual information such a group number, activity type and additional information and it was stored in our repository.

![Diagram of technical implementation](image)

**Fig. 4. An overview of the technical implementation**

The indoor subgroup located at the museum was equipped with a desktop computer with internet access and the children in this subgroup participated in the game utilizing a customized web based application we developed using AJAX. The game activities in our trials that required collaboration between the students in the museum and the students in the field have been mediated through the Activity Controller Server (ACS) as illustrated in the right side of figure 4. The ACS had a direct connection to our content repository (number 3 in figure 4) that stored the content generated during the trials. The content repository is referred to CSS (Collect, Convert and Send) and it was used to collect content generated by the different subgroups and to deliver content to the mobile phones upon request. The digital content (prepared previous to the activities) delivered to the mobile phones was also stored in the same repository.

**4. Assessment**

The main goals of our assessment were twofold; firstly, to explore how children experience these ubiquitous learning activities, secondly, to look at usability aspects related to the use of ubiquitous computing in educational contexts. For evaluating the technology we used questionnaires that were distributed to all the students after the trials. For reviewing the learning experiences we conducted deep interviews with several children and both teachers. From the 29 children participating in the trial, 18 of them described the activities as “very fun” while 11 described them as “fun”. Interesting to mention is the fact that none of the respondents described the activities as boring or uninteresting When asked if the collaboration worked well among them 22 of them answered with “very good” while 6 of them with “good” ; one child did not answer this question. When asked about the collaboration with the complementary subgroup, 9 of them describe it as “very good”, 15 as “good”, 3 as “not so good” and one as “bad”. Also in this case one child didn’t answer this question.

The interviews with the children were conducted some days after the activities. The focus of the interviews was on four questions exploring issues related to how the technology worked; the collaboration process and the overall learning experience. The first question we asked was, “What did you learn during the activity?” The main denominator of their answers was that they believed they learned about what happened with the main square during the different time periods in history but when reflecting together with them about when things happened in time; it appeared that children had problems to differentiate between different historical events. All the children were very satisfied with the activities although they main remark was that the weather was cold and rainy, especially for the outdoors subgroups.

The second question we asked was, “Which missions do you remember from that day?” It appears that the children remembered more the missions with real characters (like the blacksmith) rather than missions in which the content was sent to them via animations in the mobile phone. According to the children, the most interesting part of this activity was to guess what the new mission will be. The third question was, “What do you remember from the animations and movies that were sent to your mobile?” From the children’s answers it appears that they did not remember very clear the content of the stories from the movies sent to their phones. However, when they got a small hint about it they have been able to recall the events that happened in the stories. The final question focused on “Do you think that was an interesting and enjoyable day and do you want to join a similar activity in future?” All of them said that they are positive to participate in similar activities with different missions in the future and they would like to see more activities of this kind integrated into the school daily activities. The collaborative
problem solving aspect of the game was one of the most appreciated and useful things during this trial.

Interviews were conducted with two teachers that participated in this trial. The teachers’ general impression was that the trial was successful and they both felt that ubiquitous technologies, smartphones in this case, may help children to become more engaged in the activities. When reflecting about novel aspects of this way of learning, the teachers’ main concern was that the risk of technology potentially overshadowing the learning process. The teachers thought that this game-like-scenario helped the students to focus on the tasks more than traditional learning settings and they both felt that communication and collaboration were key issues in helping the children to solve the different tasks successfully.

5. Conclusions and Future Work

In this paper we described our current work that is an evolution of our previous research efforts [8] when it comes to contextualize situated learning activities supported by ubiquitous computing. The aim of this study was to assess how learners experienced the different activities we have developed, as well as the usability of the technical solutions we implemented. The entire process was based on an iterative design cycle guided by the ideas of design-based research. In general, the outcomes of this trial indicate that children are open and positive when it comes to using mobile technology in everyday learning activities, especially when they can be used in playful ways. Another interesting indication from the analysis of our results is that the context in which the learning activity takes place impacts the way children interpret and deal with information. This particular issue was quite evident for the outdoor subgroup where the location and environmental attributes of the context affected the overall performance. From the results of our assessments, we experienced that children paid more attention to real-life situations (like the blacksmith mission) rather than computer generated content and characters.

The type of rich technical learning environment we have presented may offer potential situations where children might get overwhelmed by the technology. This indicates that innovative situated learning activities enhanced by mobile technologies should not be regarded as stand alone activities, as they should be part of a well developed educational flow that also is combined with traditional ways of teaching and learning. Complementary post-activities that may be conducted in the classroom are needed in order to allow children and teachers to reflect upon their actions and the activities and therefore promoting metacognitive skills.

The software solutions we developed for this trial allows also for supporting this kind of post-activities in classroom settings by providing access to the data logs of all activities and communication that happened during the trial. By using principles of design-based research, we plan to improve and to modify our existing activities and technical solutions in order to increase the authenticity of the learning situations, as well as providing post-activities for fostering reflection. We will also try to develop new ways for promoting collaboration, since the children and the teachers identified the issue of collaborative problem solving as one of the most appreciated things during this trial. We will continue our efforts in this direction in conjunction with our ongoing research activities that will take place during the rest of 2007.

6. References

Chapter IX
Collaboration in Context as a Framework for Designing Innovative Mobile Learning

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ABSTRACT

In this chapter we describe our continuing efforts related to the design, implementation and evaluation of innovative educational activities supported by ubiquitous computing in the AMULETS (advanced mobile and ubiquitous learning environments for teachers and students) project. We argue that the design of innovative mobile learning activities should be guided by collaborative learning scenarios in context supported by mobile and ubiquitous technologies in authentic settings. To support this claim, we propose a conceptual framework of collaboration in context that can be used when designing novel mobile learning scenarios. This framework provides the designer with opportunities to tackle the challenges of designing for innovative mobile learning activities. To illustrate our ideas, we present the results of three trials we have conducted with children and adult students since the spring of 2006. These mobile learning activities have been designed and implemented using our proposed framework. Working with the teachers and students gave us the opportunity to design learning activities at authentic locations using meaningful content that has relevance for the school curriculum. The outcome of our efforts suggests that outdoor learning experiences supported by ubiquitous technologies should be combined with learning activities in the classroom to provide learners with meaningful activities.
INTRODUCTION

Recent advancements in mobile, wireless, and positioning technologies, combined with contextual computing, are contributing to the development 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. 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. Mobility offers new dimensions to support and promote meaningful learning activities that include features such as connectivity, social interactivity and context sensitivity (Klopfer et al., 2002). From this perspective, mobile technologies allow enhancing the learners’ context by the creation of embedded ubiquitous environments in authentic settings, thus providing innovative ways of interacting with them. They also present design opportunities for multiple kinds of collaboration to support different aspects of the learning process (Price et al., 2003).

One of the main assumptions we consider as a point of departure for the ideas to be presented in this chapter is the fact that in the coming five years, whether educators would like it or not, more and more students will bring mobile devices with wireless communication into the classroom. These devices can be in the form of tablet PCs, PDAs, cellular phones, smart phones or GPS devices. All these technologies and new forms of mobile communication and collaboration have been adopted by young people and integrated into their everyday lives. Clear indications of this can be found on sites such as www.youtube.com, www.flickr.com, www.blogger.com, and www.facebook.com. Lankshear and Knoble (2006) claim that schools ignore some of these trends and argue that mobile and wireless technologies and new media might be integrated into current school educational activities, as they are transforming and defining new literacies in teaching and learning. Thus, there are a number of challenging questions that deserve further exploration. What are the implications of using mobile computing and wireless communication for supporting teaching and learning? What new scenarios and applications will emerge? Which aspects and processes should be considered while designing new mobile collaborative solutions?

In this chapter we describe our continuing efforts related to the design, implementation and evaluation of innovative educational activities supported by ubiquitous computing in the AMULETS (advanced mobile and ubiquitous learning environments for teachers and students) project. We argue that the design of innovative mobile learning activities should be guided by collaborative learning scenarios in context supported by mobile and ubiquitous technologies in authentic settings. To support this claim, we propose a conceptual framework that can be used when designing novel mobile learning scenarios. This framework provides the designer with opportunities to tackle the challenges of designing for mobile computer supported collaborative learning (mCSCL) and mobile-learning (mLearning) environments. To illustrate our ideas, we present the results of three trials we have conducted with children and adult students since the spring of 2006. These mobile learning activities have been designed and implemented using our proposed framework. In the rest of the chapter, we will describe in further details how collaboration in context with mobile support can be used for the theoretical, conceptual and design aspects of our research activities, as well as for evaluating the results. We described the activities in the trials together with a brief explanation of the technology we have developed. We will conclude by discussing the outcomes of the trials in connection to the proposed framework and the challenges facing innovative mobile learning applications.
COLLABORATIVE LEARNING IN CONTEXT

Learning and collaboration have their roots in many different theories of cognition and development that support different type interactions between peers and experts. Piagetian theories advocate for peer-to-peer interactions between “equals” enabling conversations that can result in cognitive restructuring, while Vygotskian theories can be seen to support a peer-to-mentor interaction where the mentor, the more “able” partner, facilitates the development of knowledge and skills by scaffolding their activity (Price et al., 2003). Both schools advocate social interaction as playing a key role in learning; while Vygotsky’s work started a wider theoretical development of “cultural psychology” that together with anthropology and cognitive science formed the basis of situated learning (Littleton & Häkkinen, 1999 citing Lave & Wenger 1991 and Suchman, 1987). Situated learning (Lave & Wenger 1991) is a general theory of knowledge acquisition that is based on the notion that learning (stable, persisting changes in knowledge, skills, and behaviour) occurs in the context of authentic activities.

Learning is a social process. It happens in collaboration between people and together with technology. So, when introducing technology, the view should be shifted from seeing it as a cognitive delivery system to considering it as means to support collaborative conversations about a topic (Brown & Duguid, 2000). The central notion is that learning is enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs, and so on (Hoppe et al., 2005). Our view on collaborative authentic learning activities outside the classroom, which will be presented in the coming sections, has been guided by the ideas of Rogoff and Lave (1984). These authors have suggested that young people and adults learn more efficiently, and perform more competently in realistic settings outside the classroom than they do in many de-contextualized environments that school usually provides (see also an elaboration of learning in context by Brown et al., 1989).

Mobile collaboration in context is our suggestion towards a new framework for the design, implementation, and evaluation of innovative mobile learning activities and systems. Both collaboration and context play key roles in the design of mobile learning activities. Mobile devices are prevalent in people’s everyday lives and can be easily used in the classroom and in the field, providing more opportunities than computer labs (Vahey & Crawford, 2002). Roschelle and colleagues (2005) suggest that articulating a design framework that spans many mCSCL activities can be a key contribution to further work. Furthermore, collaboration needs to be seen from the perspective of shifting away not only the outcomes and products of collaborative work, but also towards analyzing interactions as means of gaining insights into the processes of collaborative learning (Littleton & Häkkinen, 1999). Dourish (2004) raises the importance of looking at context through interactions focusing on the question; “how and why in the course of their interactions, do people maintain a mutual context for their actions?”

Winters and Price (2005) highlight the importance of the context in which a learning activity is taking place as a crucial component for design. Context plays multiple roles in the interaction between physical and social locations, tasks and activities and the user’s situation. In the scope of our research efforts, we define context as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment.” Therefore, our definition of context relies upon a three-axis structure consisting of the following attributes; location/environment attributes, activity/task attributes and personal/interpersonal attributes. The attributes of this structure are interdependent, meaning that information about who the
user is; where the user is; what the user is doing and the interplay between these activities need to become valuable inputs to the design process (Kurti, Spikol, & Milrad, 2008).

Figure 1 illustrates the ideas previously described while using them as the central components of a conceptual framework for designing innovative mobile learning activities. A basic component of our framework is the learning activity system (LAS) simply described as a computational system and content repository that provides the technological infrastructure for integrating educational content into the context where the learning activities and collaborations are taking place. The surrounding circle of this conceptual framework defines the context where the activities are happening. The use of this design framework allows for creating engaging active learning activities in which collaboration and context are important components. From a technical perspective, the implementation of the LAS relies upon the use of different software components and ubiquitous technologies, as well as sensors in order to contextually support collaborative activities across locations (Kurti, Spikol, & Milrad, 2007). The learners interact with the LAS and with each other, thus promoting different modes of collaboration. Each one of the three context attributes described in figure 1 can be combined in set of pairs (e.g., task, location; personal-interpersonal/task-activity, etc.) or as a triplet, thus providing the proper context in which the learning activity takes place.

Our research focus is concerned with novel ways of using mobile technologies to support a range of different collaborative learning activities rather than to focus mainly on one form of collaboration around the computer screen. One of the main efforts is on designing new ways of collaboration between learners, and learners...
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

with objects in the physical world mediated by different ubiquitous technologies. The main collaboration modes we have explored in our research efforts can be described as follows: peer-to-peer, individual-to-group and individual-to-expert collaboration. Peer-to-peer collaboration happened between students within the same group that needed to discuss and to find solutions for the tasks. The tasks have been designed in the way to encourage collaboration between peers and were mainly direct without technological mediation. Individual-to-group collaboration happened while the learners were solving the tasks and encouraged to collaborate with the other groups outside or inside and thus bridging the location contexts of the same activities. This collaboration was technology mediated and relied upon text (mobile instant messaging) and content (audio/video/picture messages). Individual-to-expert collaboration happened between the children and experts. These collaborations were direct and technology mediated. These modes of collaboration have been used in the design of the different tasks to promote collaborative problem solving. This approach enables learners to interact more freely and engage in a variety of interaction and collaborative modes depending on the different contexts in which learning occurs. By linking collaboration to context our hope is to utilize the fluidity of learners’ actions, relations, and locations in a way that further defines collaboration and context in relation to mobility. In the coming section we illustrate a concrete implementation of these ideas by describing a number of activities we have recently conducted with school children and university students.

THE AMULETS PROJECT

In the AMULETS project we are exploring how teachers can develop and implement novel educational scenarios combining outdoor and indoor activities that use mobile computing technologies together with stationary computers. During 2006 and 2007 we conducted three different trials with children and university students. The first trial took place in June, 2006, in an elementary school while the second trial occurred the following December, in the town square with the same school. The third trial took place between April and May, 2007, and we collaborated with the teacher training program at our university.

For the first two trials, 55 elementary school children performed remote and co-located activities equipped with Smartphones, PDAs, GPS devices and stationary computers in the subjects of natural sciences, history and geography. The educational scenarios consisted of different stages with game like features. At the end of the learning sessions, all these activities have been reconstructed in the classroom using several visualization tools, including among others digital maps. For an elaboration of the results please see the work of Kurti et al. (2007, 2008). These types of activities provide new opportunities for children and teachers to review and to continue the learning experience in the classroom, thus supporting different aspects of learning such as exploration, discussion, negotiation, collaboration and reflection. In the third trial 16 student teachers from an environmental science course at our university used smartphones and stationary computers to explore and to learn about those aspects related to tree morphology. In all three trials we have developed and implemented educational scenarios that were designed together with teachers. In the first two cases the activities were designed to support the regular school curriculum for elementary school children while in the case of the university students the scenarios were designed in collaboration with the instructor to support a module of a university course.

In the first trial the theme of the scenario was learning about “the forest” and in the second trial “the history of the city square through centuries.” In the forest scenario conducted in the spring of 2006, 26 4th grade students (10-11 years old)
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took part working in seven groups. The activities were conducted over a two-day period with only one group performing at a time. The active challenges for the children were based on exploring the physical environment, identifying different types of tree and measuring the height and age of trees. Part of the children’s task was to record still images and video clips using the smartphones detailing how they solved the problems. This co-created content automatically encoded with metadata, containing attributes such as GPS coordinates, time stamp, and the phone ID provided rich contextual information for later use in the classroom. Pedagogical coaches supported the children with hands-on techniques describing how to measure the height of trees. Additionally, animated characters delivered content based on a specific location and tag triggered context to the smartphones.

In the city square trial conducted in the fall of 2006, 29 5th grade students (11-12 years old) participated. They worked in three groups; each group was divided into two subgroups of five students. One subgroup worked in the local museum and the second group operated in the field (the square). For this second trial, we introduced collaborative missions in order to provide the children with challenging problems. In order to solve them, children at the museum and in the field were required to collaborate using a number of mobile tools including an instant text messaging system that allowed communication between the smartphones in the field and the stationary computers at the museum. A narrative journey backwards in time relating to the square’s history was supported by animated characters and video clips delivered to the smartphones, thus providing the contextual information that was needed in order to accomplish the challenges in the different missions. Children needed to work together in order to complete the tasks including deciphering Roman numerals, finding locations for historical buildings and solving problems in the fields of history and geography.

In the spring of 2007, 16 student teachers (20-35 years old) from our university participated in this activity. The students were divided into four groups and each of these groups split into two subgroups. Again, one group became the field group while the other part became the base group. The field group had two smartphones, with one acting as the communication and messaging device with basecamp and the second phone being used as a camera. The learning activity was on how to teach tree morphology, where the student teachers used a tree key to identify different species of tree by bark, type of buds, and the surrounding environment. The field group task was to locate the trees, send images back to basecamp and collaboratively determine the tree species, as well as to negotiate answers to questions while performing tasks about the environment. After the field group completed two stages (from a total of four) they returned to basecamp and switched roles. This gave the opportunity for all students to experience both field and base work (except for one student with mobility issues who remained in basecamp for both sessions). From observing how the previous trials worked, we introduced this rotation to allow all the students to take part in both activities in order to experience the different roles. The students followed up with a post hoc activity that consisted of an informal quiz about the content they learned during this trial and discussions about the activity. The second part of the trial took place in the following weeks. The students were sent out in pairs into the field to identify two species of plants, mark their choice on a map via GPS and perform general field experiments about the surrounding environment during a three weeks period, in order to understand the impact of microclimate changes on plant growth. The latest component of this activity was a hands-on workshop with the students exploring the design of new mobile learning activities. One of the goals of the AMULETS project is to work closely with teachers and student teachers to help them understand the potential of how new
technologies can support their teaching activities. From a design point of view, these activities gave us the opportunity to allow future teachers to act as co-designers (Druin et al., 1998) in the creation of novel learning activities. In the following subsections we describe in more detail the different activities from the three trials.

**Bergunda School Trial**

This first trial took place on the outskirts of the Bergunda School (near Växjö, Sweden) in the surrounding natural environment. During the course of these activities, through collaboration (initially with the teacher, later with their peers within the group and at the end with other groups), students learned about different aspects of the forest and basic knowledge that could be used to identify trees in their environment. Once stage one was completed, children were introduced to the field activity including a short hands-on workshop, providing them with the necessary knowledge about how to use the different mobile tools available. The collaboration occurred in peer-to-peer and peer-to-group contexts for the mobile learning activities. For the first task, the children needed to identify a particular sort of tree out of three different kinds of tree located in the surrounding forest. Once they identified the trees and received some additional information on the smartphone, they needed to scan the correct semacode tag (a 2D barcode tag that can be read by a camera-enabled mobile phone for embedding URLs to specific location, see: http://www.semacode.org/) placed on one of the trees. In the case of choosing the incorrect tree the children received additional information describing how to proceed. Upon selecting the correct tree, a video animation was sent to the smartphones in order to give the children the required information to proceed to the next mission.

These exploratory and task-based activities continued by encouraging the children to learn how to measure the height and age of the surrounding trees. In addition, they gained some knowledge about when trees are ready to be processed by the

*Figure 2. illustrates the flow of the learning activities from the pre-activities, to the mobile learning application, to the post-activities*
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forestry industry. During the entire field trial, the children documented their activities by taking photographs and videos that contained automatically generated GPS metadata. As part of the game related aspects of this activity, our system collected the time that it took for each group to accomplish the different tasks as well as the answers to each mission from the different groups. All this data was stored in our repository and we used it for further purposes in the follow up activities. At the end of the two day event, all the children were gathered together in the classroom. The follow up activities took place back in the school where all groups presented and discussed the content created during the trial while this content was tailored to a specific location as explained before. At the end of the activity, the results (times and numbers of points) were presented and the winner was announced. This trial was designed as a pilot test. The learning activity was divided into three stages including a pre-activity (where interaction was primarily group-to-expert, as illustrated in the top left image (a) in figure 2), a field activity (where collaboration was mainly peer-to-peer as illustrated in images (b) and (c) in the figure 2) and a post activity (where knowledge exchange was based on individual-to-group basis as illustrated in section (d) of figure 2).

Växjö Square Trial

This trial took place at the main square and at the museum of history in the city of Växjö. The overall activity was divided into three sessions over two days. The students were divided in three groups of 10 children. Additionally, each group was divided in two subgroups of five students, where one subgroup was working indoors in the museum, while the other group was outdoors in the city square. In this trial, we introduced several new features that included collaborative learning activities between the indoor and outdoor groups. The indoor and outdoor groups were required to communicate and collaborate across different locations using mobile technologies in order to accomplish a task. The collaboration modes used in this trial were peer-to-peer (between children in the same group) and group-to-group (between children in different groups and in different locations, indoor and outdoor). We relied on the use of jigsaw techniques (Aronson et al., 1978) for the pedagogical design in different locations, thus creating the conditions for our concept of collaboration in context. For all these activities we explored how different collaboration modes worked between the children in different locations.

Figure 3 illustrates several of the tasks in this trial that occurred simultaneously, in images (a) and (b) the learners are decoding a roman numeral on the governor’s house. Images (c) and (d) illustrate continued negotiations between the groups to determine the age of the governor’s house. In images (e) and (f) the outdoor group has just sent a photograph of the square and the indoor group is directing them to where a historical building once stood in order to relate what the square looks like today to what it looked like in the 19th century. The activities were designed around group collaboration to solve the challenges for each task. For the five tasks in this activity, the groups needed to discuss and negotiate, thus switching roles regarding the different actions and decisions to be taken depending on the task. We used mobile instant messaging (IM) and the exchange of digital photos produced by the children to support the discussions and negotiations. The outdoor subgroup was equipped with three smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding the semacode tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. Student teachers supervised the groups during the activities. While the outdoor subgroup was in the field, the indoor subgroup
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was in the museum. We used animated characters and short video clips to provide information and additional help for the students.

**Student Teacher Trials**

This trial took place on campus at Växjö University in the spring of 2007. We worked with 16 student teachers, divided into four groups. Each of these groups was divided into two subgroups. The field groups were equipped with two smart phones, one for game control and information and one for digital documentation. The control smartphone was used with semacodes for the control of the learning activities and for sending messages via a semacode tag, while the second phone automatically delivered the photographs and audio files to base camp once the students took an image or finished recording. The field activities focused around the identification of four different families of trees, where the outdoor group collected data (images, video, and audio files) via the smartphones. The indoor group analyzed the images, audio, and sound in order to determine, with the support of a tree taxonomy instrument, to which family the tree belonged according to leaf buds, bark colour, and other environmental factors. For this third trial we further refined the learning activity by running simultaneous trials with four groups and splitting the indoor and outdoor ses-

Figure 3. Växjö square trial activities
sions between them, enabling all the students to experience the different roles and aspects of the trial. The collaboration modes promoted in this trial were primarily based on peer-to-peer and individual-to-group collaboration. Images (a, b, c, & d) in figure 4 illustrate how the indoor and outdoor groups needed to collaborate to solve the tasks. The images (e & f) show the brainstorming process and idea presentations. In this trial we tried to scale down the number of devices and control the communication to be more effective.

The field students set out for their respective first stations, where after scanning the “startcode” they received an introduction, short audio instructions and a special tree identification form. They used the digital documentation phone to sent photographs and audio recordings to the base station using a special communication semacode. The groups needed to remotely collaborate using the mobile media and a Web interface in order to identify the tree species.

In addition, the field group used the phones to document the environment and to answer additional questions that were designed to inspire them to explore the tree’s surrounding environment. Meanwhile, the indoor group compiled additional information for the post activities. For the post activity, the students worked together as a group to reflect over the content generated by the different teams, they participated in an informal quiz and discussed how the trial worked out from a pedagogical point of view.

The second part of the trial comprised a three-week period where the students did traditional
fieldwork, collecting environmental data. After this activity, the students participated in a future technology workshop (Vavoula, Sharples, & Rudman, 2002) organized by one of the researchers to flesh out how a mobile learning activity could be designed in this particular domain. The students worked in four groups, brainstorming and testing their ideas, and the workshop ended in a presentation of the best concepts followed up by a general discussion. This trial was designed with two goals in mind. The first goal was to support a module of the environmental science course for the student teachers, thus providing an opportunity for them to introduce a mobile learning component into their course. The second goal of this trial was to actively involve the student teachers in the design process of mobile learning in order for them to become co-designers of new mobile applications. Figure 4 illustrates the outcome of this trial. In the top four images we see the different groups collaborating and the bottom two images show the brainstorming and the idea presentations.

Table 1. Applying our conceptual framework

<table>
<thead>
<tr>
<th>Trial</th>
<th>Location / Environment</th>
<th>Task / Activity</th>
<th>Personal / Interpersonal</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergunda School</td>
<td>The main activity was conducted outdoors and supported with pre and post activities indoors/ School and surrounding forest</td>
<td>Serial tasks about nature and history of the local forest/ Co-located</td>
<td>Collaboration between the groups and then group knowledge exchange in the post activity</td>
<td>Peer-to-Peer</td>
</tr>
<tr>
<td>Växjö Square</td>
<td>The main activity was conducted both in indoor and outdoor settings/ Local museum and town square</td>
<td>Parallel and simultaneous tasks about the history of the square and live in past times/ Co-located Remote</td>
<td>Collaboration between indoor and outdoor groups was mediated using text and content mode</td>
<td>Peer-to-Peer Individual-to-Group</td>
</tr>
<tr>
<td>University</td>
<td>The main activity was conducted both in indoor and outdoor settings/ University lab and surrounding nature</td>
<td>Parallel and simultaneous and shifting roles. Tasks about tree morphology and the ecosystem/ Co-located Remote</td>
<td>Collaboration between indoor and outdoor groups was mediated using text and content mode</td>
<td>Peer-to-Peer Individual-to-Group</td>
</tr>
</tbody>
</table>
Applying the Conceptual Framework

Price and colleagues (2003) have suggested a framework for supporting multiple interactions between individuals and groups that provides multiple collaboration opportunities. We hope to address the complexity and fluidity of introducing context in collaborative learning environments using our conceptual framework (Figure 1). In Table 1, we have tried to categorize the different trials mapped according to the components of our framework based on location/environment, task/activity and personal/interpersonal type of collaboration.

METHODOLOGICAL CONSIDERATIONS

Design studies are typically conceived as test-beds for innovation. One of the main objectives of this study was to investigate the possibilities for educational improvement by stimulating new forms of learning (Design-Based Research Collective, 2003). We consider our efforts as being an attempt to create innovative, socially-situated exploratory learning experiences through elaborated learning sequences supported by ubiquitous technologies. Within the context of our efforts, the notion of socially-situated extends to the idea of learning activities guided by the context in which they are taking place.

Design-based research is an attempt to combine the intentional design of interactive learning environments (ILE) with the empirical exploration of our understanding of those environments and how they interact with individuals (Hoadley, 2004). The primary aim of Design-Based Research Collective is to develop domain specific theories (Mor & Winters, 2007). Therefore, we consider it as a suitable methodological approach for the field of mobile learning. A recent view regarding the design of ILEs is presented by the Design-Based Research Collective group (2003) who argue that design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice. Based on those claims, design is central in efforts to foster learning, create relevant knowledge, and advance theories of learning and teaching in complex settings. According to Edelson (2002), the emerging design-based research paradigm treats design as a strategy for developing and refining theories. Design-based research follows an iterative cycle of designing, implementing, analyzing and modifying.

The research efforts presented in the former sections were conceived and implemented as inspired by the ideas and rationale suggested by this methodology. Such research is more akin to ethnography than to quantitative studies; the emphasis is on design processes as planned, observed and reported in their natural settings. In our particular efforts, the different educational scenarios we developed were created based on prior cognitive, educational and technological research, relevant learning goals and content pedagogy, and knowledge of the specific educational context. Different scenarios were implemented and a variety of data were collected and analyzed to determine the success of the design. Since a successful educational design should operate as an integrated system, the critical elements of the design were identified and their interactions in the educational setting were analyzed. If those elements were not working in the expected way, then the design was modified based on the findings and a revised prototype was implemented. In this sense, design-based research has some of the aspects of a formative evaluation, especially as it informs the next version of the ILE. In the research efforts described in this chapter we have used design-based research as means of exploring how collaboration and context can be used to support the design of innovative learning activities.
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Trial Design Issues

Roschelle and colleagues (2005) have defined co-design as a highly-facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate the prototype’s significance for addressing concrete educational needs that support our situated learning aims. For the AMULETS trials we have worked in this manner where teachers, researchers, and students engaged in co-design together. Our aim with the overall project is to provide mobile learning tools and methods for teachers to use in different educational settings.

For the first trial at Bergunda School, we developed the technology and worked with iterative design in conjunction with the teachers. This was our initial prototype in terms of how the activities worked out in the pre and post sessions with the children. As shown in Table 1, the first trial took place outdoors with the groups having peer-to-peer collaboration. For the second trial, working with the teachers helped us to broaden the concept of geographically distributed mobile collaboration between two groups, providing a space for the children to collaborate and negotiate in order to solve the tasks. The collaboration between the different locations was mediated by the technology of instant messaging and the exchange of photographs between the smartphones and stationary computers. For the third trial, we extended this form of collaboration by having all the students experience both the indoor and outdoor work. Moreover, this activity was designed in a way to support reflection and knowledge sharing using rich media content and via visualizations using a specific web application we developed for this particular purpose.

The trials have been designed in the form of game-based activities. One of the main pedagogical challenges of these activities was to design learning tasks that fostered collaborative problem solving skills within the same subgroup and with their peers. Most of the activities were designed in such a way as to promote the division of labour, fostering collaboration, first within subgroups in the trials and then later across the groups in the second and third trial. During the different stages of the trials, children and students needed to use mathematical and navigational skills, combined with reasoning and argumentation. Strong negotiation skills were needed for the successful accomplishment of the tasks. In addition, group discussions and interactions, as well as collaboration, were also activities that enriched the learning experience. The integration of all these different features into a realistic scenario offered children and students a challenging learning environment.

THE TECHNOLOGICAL ENVIRONMENT

In order to support the different learning activities we have developed and implemented a number of mobile tools and applications. In the technical architecture presented in Figure 5, 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. The activity generator contains the activity control system (ACS) that enables collaboration between users and devices while retrieving and storing the content and it controls the flow of the learning activities. The collect, convert, and send (CCS) component is the content repository and it is used to collect content generated by the different groups and to deliver content to the mobile devices and computers upon request. The educational content delivered to the mobile phones and computers is also stored in this repository. The LAS manages the automatic generation of metadata, storing the tags and the content in the CCS that the two other
components, namely the collaboration tools and the presentation engine, create and utilize.

The collaboration tools provide the literal bridge between groups outside and inside through instant messaging, images, and audio. For the outdoor activities 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 interacting with the sensors. The collaboration tools enable the technology-mediated support for remote groups to work together by providing text, content, and awareness modes. For the text mode collaboration, support was provided by a mobile instant messaging application we developed using instances of the Nokia Raccoon software. Nokia Raccoon has a built-in python script for enabling mobile text communication via instant messages. In addition, we used these features to send photographs, video, and audio files from the mobile phones to the LAS, thus linking the content delivered and created by the group. All the content generated by the learners contained contextual information such as group number, activity type and additional information that was stored in the CCS. The user-generated data was handled by a python application that ran
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on the smartphones that automatically sent the meta-tagged data to the CSS. Depending on the different learning situations, this content and its associated metadata was available for immediate access to the indoors group via the presentation engine.

The presentation engine provides the visualization tools to support the collaboration during the activities and for reflection in the post activities through the use of metadata and rich media content generated during the group activities. See Figure 6 for an example of how the presentation engine can render the data from specific tasks and actors in the learning scenarios. The fourth block of this architecture consists of the sensors and actuators that support the outdoor activities with location and visual tags (semacodes) to trigger or record events. For the indoor activities the children and students interacted through a web interface linked to the presentation engine, thus providing contextual content and connection to activities performed by the outdoor group.

RESULTS

Assessing the learning processes and outcomes in the type of ILEs presented in this chapter is a very complex task, as there are many variables involved (different tasks, roles, contexts, etc.). Existing and validated methods for pedagogic evaluation for these types of specific applica-
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tions need to be refined in order to accommodate the properties of mobility and context. In our particular efforts, we used several techniques for data collection including questionnaires and interviews with the children, students, and teachers, as well as observation protocols and stored data files. The questionnaires were mostly used to evaluate usability aspects while the interviews with children, students, and teachers were used more to evaluate the pedagogical related aspects of the trial. The digital content generated during the trials were saved on the CCS repository and we have used those data in different ways in our activities and analysis. In the first trial, the stored data have been used for reconstruction of the field activity in the classroom settings. In the second and third trials, the server log files have been used to trace the messages exchanged between the indoor and outdoor subgroups to investigate the collaboration that occurred between these subgroups. Additionally, in the third trial, data storing techniques were further developed to allow further exploration and visualization of how the activities unfolded by task and group. The main focus of our assessment was to investigate how we could use the conceptual framework presented in section 2 as a basis to explore the technology, pedagogic, and collaborative impact of the mobile learning activities. Taylor (2004) suggests some key points to consider while evaluating mobile learning according to the following:

- The learning opportunities presented by the new mobile technology
- Its (potential) impact on the way people perform learning tasks
- Its (potential) impact on the human social process and interactions
- How these in turn are changed or modified by the technology

We combined Taylor’s (2004) task based approach for the evaluation of mobile learning environments with our conceptual framework in order to develop an assessment strategy to analyze the data we collected during the trials. Table 2 presents this strategy, illustrating how context can be used to evaluate the learning activity, describing which key points to look at, and which techniques should be used for data collection.

For the trials we chose to evaluate the learning opportunity related to the location & environment based on the nature of the field trip based activities. We used the task & activity components to look

Table 2. Assessment framework

<table>
<thead>
<tr>
<th>Context</th>
<th>Evaluation</th>
<th>Type</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location/Environment</td>
<td>Learning Opportunity</td>
<td>Field Indoor</td>
<td>Survey Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outdoor Remote &amp; Co-Located</td>
<td></td>
</tr>
<tr>
<td>Task/Activity</td>
<td>Impact on Task</td>
<td>Usability</td>
<td>Survey Observations Data</td>
</tr>
<tr>
<td>Personal/Interpersonal</td>
<td>Impact on Social Processes</td>
<td>Collaborative</td>
<td>Survey interviews Log files</td>
</tr>
<tr>
<td>Collaboration modes</td>
<td>Impact of Technology on Collaboration</td>
<td>Learning Outcome Interviews, Survey, Log files</td>
<td></td>
</tr>
</tbody>
</table>
at how the usability aspects related to the use of mobile technologies that may have some impact on the way the activities here were conducted. For the personal & interpersonal we looked at the impact of technology on the collaborative learning aspect and for the collaboration modes how the technology may have some influences on the learning outcome. The data collected during the trials and saved on the CCS repository have been used in different ways in our activities and analysis. The following subsections are used to evaluate the three trials based on the ideas presented in Table 2. Section 6.1 looks at usability issues with the learning activity based on the task, 6.2 on how technology impacted the social and collaborative activities, and 6.3 on the learning outcomes shaped by the technology.

**Impact on Task and Usability**

During first two trials, we conducted 55 questionnaires exploring aspects such as perceived ease of use, satisfaction and peer collaboration mediated by ubiquitous technologies. Of the 26 children who attended the first trial, 22 of them described the activities as “very enjoyable” while the other four described them as “enjoyable.”

Of the 26 students that participated in the first trial, 16 of them found the usability of ubiquitous technologies as “very easy to use” while the other eight for the same question answered with “easy to use.” Only one child described the technology as “not easy to use.” In the second trial, the usability questionnaire for the technology was made separately for the indoor and outdoor subgroups since they used different technological tools. From 29 students that participated in this trial, 14 of them belonged to the outdoor subgroups while 15 belonged to the indoor groups. In the outdoor group, eight of the students felt the smartphones were “very easy to use” while the remaining six described them as “easy to use.” From these 14, only four of described the use of semacodes as “very easy,” nine described them as “easy” and one described the use of semacode as “difficult.” Six of students described the instant messaging service used as “very easy;” the other six describe it as “easy” while the last two did not answer this question.

![Usability](image_url)
For the third trial, based on the questionnaires of the 17 students who responded about the usability, 13 reported that the technology was easy to use, three felt it was difficult, and one did not answer. Semacode reading was the most difficult technology to use according to the responses of 13 of the students. We observed some difficulties in the use of the semacode application. The children and students also requested better possibilities for communication between basecamp and the field. Figure 7 illustrates the ease of use of the technology across the three trials.

**Impact on Social and Collaborative Activities**

For evaluating the impact of mobile technologies on the social and the collaborative aspects of the different trials we used questionnaires, interviews, and observations. In general, across all the trials, and based on the interviews we conducted, all the participants enjoyed the activities and thought they were fun. From a pedagogical perspective, the teachers believed that the game format and the narrative style of the activity helped the children to concentrate on the task. They both felt that the communication and collaboration tasks the children needed to solve throughout the activity were key components, helping the children to learn social and problem solving skills embedded in the history curriculum. From the instructor’s point of view, the social and collaboration task required by the trials and the workshops pushed the teachers’ students to discuss more about the learning process than in previous courses.

In the second trial, we used questionnaires to assess the collaboration modes. For the outside groups, when asked about the collaboration with the indoor subgroup, only four of them defined it as “very good,” eight of them defined it as being “good” and two described it as “not so good.” When asked about the collaboration with the outdoor subgroup, five of them described it as being “very good,” seven of them described it as “good” and one child each thought that this collaboration was “not so good” or “bad.” Here also, one child did not answer this question. Figure 8 shows the value of collaboration for the students in trial 2, where similar questionnaires regarding collaboration were conducted with 16 student teachers. Based on their responses, we can say that eight preferred the field trials, while seven enjoyed both.
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Figure 9. Value of collaboration in trial 3

and two liked the indoor activities. From the 15 children participating in the indoor subgroups, 13 of them described the collaboration between them as “very good,” one described it as being “good” and one did not answer this question.

Overall, the students preferred face-to-face collaboration and felt that working together was most efficient. Figure 9 is a breakdown of how the student teachers ranked the importance of collaboration during the experiment by whatever mode they preferred.

How Technology Influences the Learning Outcome

In order to assess the impact of the technology on the learning outcome, we used questionnaires, interviews, structured observations, and the stored data files. The interviews with the children in the second trial were conducted some days after the activities. The focus of the interviews was on the overall learning experience. The first question we asked was to the children, “What did you learn during the activity?” The main denominator based on their answers was that they believed they learned about what happened in the main square during the different time periods in history, but when reflecting together with them about when things happened in time. It appeared that children had problems to differentiate between events that took place in different time periods.

For the student teachers, we asked similar questions about the activity and similar responses were given. In terms of what they learnt through the activity, they recognized that the different sub groups learnt different things during the trial and in retrospect they realized that they needed to discuss more in the post activity. The students requested better possibilities for communication between the group indoors and the groups in the field. A hands-on workshop was organized around a future technology scenario activity, as a second part of the student teacher trial. The goal of this activity was to explore and brainstorm about new ways of enhancing traditional fieldwork using mobile technologies. The purpose of this activity was to encourage teachers to think and act as co-designers of mobile learning activities rather than being only users. One major outcome of this activity was the teachers’ concerns about usability aspects of the technology and transparent interactions. In general, they imagined a future mobile learning device that would have more ease of use features than the current crop of smart phones.
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Analysis

The teachers’ general impression was that the trials were successful and they both felt that mobile technologies (smartphones in the case of these trials) may help children to become more engaged in the activities. When reflecting about novel aspects of this way of learning, the teachers’ main concern was the risk of technology potentially overshadowing the learning process. The teachers thought that this game-like-scenario helped the students to focus on the tasks more than traditional learning settings. For the third trial, the instructor felt that the use of mobile technologies helped to involve the student teachers in learning how to teach the subject and presenting them with opportunities to face learning challenges in authentic situations. In terms of what they learnt through the activity, they recognized that the different subgroups learnt different things during the activity and now in retrospect realized that they needed to discuss more in the post activity.

Similar to younger students, the additional content delivered to the smartphones was not recognized as important.

For the first two trials with the children we asked the following question, “Do you think that was an interesting and enjoyable day and do you want to join a similar activity in future?” From a quantitative perspective, and based on responses from the questionnaires, all of the children (55) said that they are likely to participate in similar activities with different missions in the future and they would like to see more activities of this kind integrated into the daily school activities. The student teachers had more mixed feelings about the learning opportunity; out of the 16 students, nine would consider using mobile technology in their future classrooms if relevant, four were not interested in the technology, since they felt that for very young children, it was not relevant, three were positive towards using the technology, and one did not answer. From the interviews they all expressed concern about how to get access to the technology when they become teachers.

In summary, based on the results presented in the previous sub-sections, we can observe that the mobile learning solutions we developed provided added value to the locations in the different trials. Like all new technologies introduced in educational activities there is always a risk of a technology-centric approach away from the learning, but with careful pedagogical planning and the involvement of teachers in the design process this can be avoided. Both the children and the students expressed that face-to-face collaboration was more valuable than the technology during the trials and during the post-activities. Based on our experiences in the second trial, real-life situations that the children encountered during the activities mattered more than the computer generated animated characters delivered to the mobile devices. In general, both children and students feel that the technology can be used for appropriate situations, while the new teachers expressed concern about what tools could help them create future applications easily. From a usability perspective and an interaction point of view, we can clearly see difficulties in using semacodes as the main means for triggering events in the field while working with the smartphone. A key factor in this respect is the need of training sessions to make users become more familiar with this mode of interaction. This fact implies that future efforts should focus on how scaffolding techniques can be integrated into the application. From a social and collaborative perspective, the game-like features worked well for the design of the learning activities and for the overall experience. Both the children and the students expressed enjoyment in working together and felt that the face-to-face collaboration was the most enjoyable. This does raise some issues for the future design of activities in how we may shift the activities to different patterns of collaboration.
DISCUSSION

Currently, mobile devices are not perceived any more as simple communication tools; they can be seen instead as new social tools to support human collaboration and interaction. In this chapter we have presented our view about the design of innovative mobile learning based on new “social technologies.” The hope is that learning in mobile settings can be made more effective by expanding how people collaborate while taking into consideration context as a design parameter. The focus of this chapter has been to explore how innovative mobile learning scenarios can be designed by defining new ways of collaboration and interaction between people and devices. We have presented our thoughts in this direction by proposing a design framework based on our view of context and collaboration. The general framework for design and evaluation presented in this chapter offers new possibilities for addressing the challenges for mCSCL and mLearning. Integrating different aspects of the learners’ context into the design of collaborative learning activities can provide new modes of interaction that may help to enhance different aspects of learning. This latest aspect is especially important when it comes to bridging indoor and outdoor learning activities. Our framework is open enough to provide an underlying foundation for future research efforts and open to different theories. By providing mobility to the learners we can offer more authentic learning opportunities. According to Jonassen, Peck and Wilson (2000) meaningful learning will take place when learners are engaged in real world activities. This approach to technology-enhanced learning may contribute to a richer, more authentic grounded experience than conventional learning activities conducted in classroom settings using traditional material such as textbooks or demonstrations of experiments.

The use of design-based research provided us with a methodology that combines the practice and theory of learning. Using this approach combined with working together with the teachers and the students gave us the opportunity to design learning activities in authentic locations using meaningful content that has relevance for the school curriculum. The co-design activity together with the student teachers aimed to address the needs of creating a simple toolbox for both students and teachers. The outcome of our efforts suggests that outdoor learning experiences supported by ubiquitous technologies should be combined with learning activities in the classroom to provide learners with meaningful activities in order to:

- Learn and to explore a topic in authentic settings,
- Collaborate in order to construct common knowledge,
- Reason and to argument in order to come to the solution of a problem,
- Reflect upon things and to support abstract thinking

Our explorations into collaboration in context evolved over the three trials presented in this chapter. In the Bergunda School trial, the students worked in groups in the field. In the second trial at the Växjö Square, we introduced the co-located subgroups collaborating in different location scenarios while the collaboration was mediated by mobile technologies. In the third trial, the student teachers rotated between the outside and the inside activities, thus providing all students with learning experience at the different locations. Based on the assessment of these trials and the post activities, we have learned that the users placed high value on the collaboration aspects of the learning activities and the need to develop easier forms of communication for collaboration in context using mobile and ubiquitous technologies.

Mobile and ubiquitous technologies offer the potential for a new phase in the evolution of technology-enhanced learning, marked by a con-
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

Continuity of the learning experience across different learning contexts. Chan and colleagues (2006) use the term “seamless learning” to describe these new situations. Seamless learning implies that students can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using their personal mobile device as a mediator. These scenarios include learning individually, with another student, a small group, or a large online community, with possible involvement of teachers, relatives, experts and members of other supportive communities, face-to-face or in different modes of interaction and at a distance in places such as classrooms, outdoors, parks and museums. Seamless learning spaces refer to the collection of the various learning scenarios supported by personal (and also collaborative) mobile technologies. In the different cases illustrated in our trials we have presented several examples in which we have implemented seamless learning spaces by augmenting physical spaces with information exchanges as well as using geospatial mappings between the mobile device and the real-world that facilitate navigation and context-aware applications. According to Pea and Maldonado (2006) these last two features play an important role in designing mobile applications with an emphasis on inquiry processes, social constructivist theories, and distributed cognition designs.

FUTURE RESEARCH DIRECTIONS

These experiments have provided us with some ideas to develop a set of recommendations for the design of new trials in the AMULETS project and others efforts. In order to support the design of innovative educational practices it is necessary to take an integrative perspective to technology-enhanced learning where pedagogy and learning theory are the driving forces rather than mobile technologies. From this perspective, mobile technologies can be used as collaborative mindtools (Hoppe et al., 2005) that help learners (in both formal and informal settings) to conduct activities and accomplish results that are impossible to achieve without these technologies. Thus, it might be beneficial to continue to elaborate this framework to help designers to identify educational situations and requirements in which mobile technologies fill a unique role while trying to support innovative educational practice. By looking at the application of our conceptual framework (Table 1) and the assessment framework (Table 2) we can observe how mobile collaboration in context can be used to guide future work. Further development and implementation of these ideas can result in guidelines that can be used for the design of technology-enhanced learning environments using mobile technologies to support innovative educational practices.

In our future work, we plan to improve and to modify our existing activities and technical solutions in order to increase the validity of the learning situations, as well as providing post-activities for fostering reasoning, argumentation and reflection combining mobile media, positioning techniques and digital maps. From a technical point of view, we will explore how to integrate RFID tags and Near Field Communication technology in our technical platform. By doing that, we want to assess if this technology facilitates the ways people interact with mobile phones and the objects compared with the visual tag solutions we have been using until now. We will also try to develop new ways for promoting collaboration, since the students and the teachers identified the issue of collaborative problem solving as one of the most appreciated things during these trials. Another research direction we will be exploring is how contextual information and positioning technologies can be used to deploy mobile and ubiquitous learning environments that will be responsive to the learners and the context in which the learning is taking place. We are starting to explore how intelligent support techniques can be integrated in these environments and we are in-
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Involved in an EU initiative together with colleagues from the UK, Finland, and Holland where we are investigating new methods and technologies for efficient context-aware collaborative learning for workplace learning situations.

ACKNOWLEDGMENT

This work has been partially supported by the Swedish KK-foundation and Växjö University under the ICT and Teacher Training program, project Young Communication. Additional funding has been provided by the Internet Infrastructure Foundation of Sweden, project MeMiMo. We thank all our team members, especially Martin Svensson and Oskar Pettersson for the technical support and Jonas Wercén, Gerd Ouchterlony, and Louise Roth for the pedagogical concepts and content.

REFERENCES


Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities


Additional readings


Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities


Paper IV
1. Introduction

New forms of mobile communication and collaboration are rapidly being adopted and integrated into young people's everyday lives on a global scale. Multimedia capable mobile phones, MP3 music players, digital cameras, and GPS devices are merging into single powerful units that rival the computational power of laptops at the fraction of the cost with genuine portability. These devices have provided new opportunities for researchers, educators, and enterprise to explore how mobile games can be used to support learning practices. Recently mobile games have begun to be taken seriously within the educational arena. These recent proliferation of mobile games makes them a fertile ground for the development of new resources to support learning (Facer et al., 2004). Mobile games can promote children getting involved in different tasks such as exploration, content generation, collaboration, problem solving and navigation in space; all these activities can be seen as important components that support a wide variety of cognitive and social skills. By adopting a design approach for mobile learning activities that takes in consideration the diversity of mobility and context. By focusing on the entire flow of the learning activities where mobile technologies are just part of the activities can provide richer opportunities for data collection and evaluation. The flow of these mobile activities can be "caught" by using techniques like automatic and collaborative tagging.
ways to analyze and understand the nature of these novel learning practices and outcomes that impacts the future design of new activities.

2. Game Description

The paper presents Skattjakt (Treasure Hunt in Swedish), a game that has been conceived and implemented to promote physical activity and collaborative problem solving. The game is inspired by the ideas behind treasure hunt activities and the sport of orienteering, a traditional Scandinavian running sport involving navigation with a map and a compass. The activities in the game explore informal skills such as learning about local history, reading maps. The game requires different degrees of collaboration between team members to solve the mystery. Up to six teams can simultaneously compete using mobile phones, as they progress through the playing field with detours for wrong answers. The playing field is spread out over the university campus with seven locations. A strong narrative drives the players to help a ghost solve a mystery about her lost husband who built the castle on campus. The mobile interface includes an interactive map with the different marked locations where the players can zoom in, out, and pan to see the entire playing area. Figure 1 illustrates the full map of the playing field with the detours and mobile game interface. Children playing the game can communicate with the game server that provides the logic and scoring for the game.

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Designing Mobile Games that Explore Novel Learning Practices with Co-Design
The game has been part of two completed trials in 2007 in February and June. Currently the game is part of a third trial in the fall of 2007. The game has been a central part of informal learning activities and iteratively developed, for the first as a proof of technology and part of co-design effort for a university course on mobile games. For the second trial part of weeklong summer school class for girls (aged 13-15) where the games acted as a starting point for game design course where the outcome was two student created game concepts. Currently the game is being used in an elective class at a local middle school (aged 13-15) where the outcome will be a new co-designed game to run in December 2007 for other students. The game has acted as a catalyst to get the students and teachers involved in the design process providing a bridge to more formal learning activities.

3. Approach

The pedagogical design of Skattjakt has been inspired by recent social constructivist perspectives (Jonassen et al., 2002) that regard learning as enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices e.g. language, use of tools, values, beliefs, etc. Social constructivism asserts that a particularly effective way for knowledge-building communities to form and grow is through collaborative activities that involve the design and construction of meaningful artifacts as well as the exchange of information. An implication of this view on learning with regard to the design of novel educational activities supported by mobile technologies is that effective and meaningful learning may not take place if these technologies are used only in traditional ways. Thus, designing and implementing learning activities that truly support innovative educational practices is a challenge.

Co-design can be defined as highly facilitated, team based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes and evaluated each prototype’s significance for addressing an educational need (Penuel et al., 2007). The co-design process relies on teachers’ ongoing involvement with the design of educational innovations, which typically employ technology as a critical support for practice. But at times these design approaches do not necessarily use the inherent qualities of mobile technology to catch empirical data that can be used in the evaluation process or involve the students directly into the design process. Inspired by design-based research that combines educational theories and practices to look how individuals and groups interact in complex settings (Hoadley, 2004). The Skattjakt project is using social constructivism perspectives with the methods of co-design and design-based research to explore how informal game activities playing and making can be used to better understand how to design new mobile game-like learning
activities.

4. Assessment

The game with the surrounding activities has provided us with a way to look at informal learning practices that improve our understanding of the different aspects of the learning processes and its outcomes. Skattjakt has also enabled us to look at co-design and other participatory methods that can have a big influence on the future design of mobile games and learning activities by allowing the students to become actively involved in the design of their own learning material. We have written field notes, made interviews, have been “hanging around,” collected documents used in the different learning situations, and in addition have had deep interviews with teachers and learners. The aim of using ethnographical methods has been to “come closer” to learning in real settings, find out “how learning is taking place” – how artifacts are used, how the content of learning is established, what the interaction between the participants looks like, and so on. Over the course of two trials and with ongoing classes we have used surveys for the players and stakeholders, simple observation forms for researchers, provided additional mobile phones for the players for photographic self-documentation with GPS tagging, and simple data files generated by the game system for collecting data. In the later trials this content was visualized and reviewed to create new content for future games. The top row of figure 2, are images from the 280 self-documented photographs the students in the second trial took while playing the game. The bottom row is the workshop in progress and a detail of a student created game concept.

Figure 2. The photographs below present the images taken by players in the second trial and images of the workshop conducted during the summer school.
According to Vavoula (2007), mobile learning should be evaluated according to the following 3 levels namely: a Micro level: assessing user's experience of the technology including usability aspects and utility of functions, a Meso level: looking at the user’s learning/educational experience and a Macro level: in which the evaluator tries to understand the impact on learning/teaching practice as well as the appropriation of the new technology and new practices. All these different levels can help understand some of the on-going learning processes as well as they can also assist us to identify problems and further requirements. For assessing the value of co-design we have primarily worked in the Meso and Macro levels utilizing the ethnographical approaches presented above. Figure 3 presents how different data can be caught and used together with the co-design process to explore how design and evaluation can be used to “catch” the flow of the learning activity that takes in consideration the additional challenges of mobility. Using this approach enabled us to use various methods for data collection about the different activities with a loose framework for evaluation. In the first pilot trial we used surveys only and for the second trial along with surveys we used, the photographic self-documentation with additional mobile phones, the use of simple observation conducted by researchers, and a daylong workshop for 10 of the players, which resulted in new game concepts. By looking at the results, we begin to see some patterns across the surveys, interviews, and the photographs the students made during the experiment. The patterns between how the different stakeholders viewed the perception of collaboration between the players, the observers, the researchers, and the teachers. The data from the interviews was a selection of six girls from the second trial where four of them also participated in the workshop activity. The interviews where conducted during the workshop the day after the game. We also used observation and procedures sheets developed in one of our other projects that helped the observers to look at aspects such as attitudes, engagement, collaboration, understanding of the task, the game experience, roles of players, and cultural issues.

<table>
<thead>
<tr>
<th>MICRO (Usability)</th>
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<th>MACRO (Impact)</th>
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<tr>
<td>Survey, Observations, &amp; Interviews</td>
<td>Game Workshop</td>
<td>Game Workshop Game Class</td>
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<td>Game Data</td>
<td>Survey, Observations, &amp; Interviews</td>
<td>Survey, Observations, &amp; Interviews</td>
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<td>Self-Documentation with camera phone &amp; GPS</td>
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Co-Design

Figure 3: How co-design is used across the learning activity
develop meta-level reflections on strategies for learning by making new games (Facer et al., 2004). At the same time this provides relevant design input by the inclusion of students / players in the process that provides additional insight to evaluate the learning process.

References

The six observers were a mixed group of researchers, university students, and members of the local orienteering club. In the current trial 11 students are participating in the class. They have played the game with 10 additional students from another school. Surveys, interviews, observations, along with the game data have been collected during the game. Exploring the co-design practices has provided additional information beyond the data we collected from the surveys and interviews. By working with the students in the post game activities we could see how learners want to become engaged in the activities by connecting the skills of playing games to making games and relating this knowledge to other learning domains. The preliminary indications of our results offer promises for understanding how informal mobile games can be used as learning tools in traditional educational settings by actively involving students in the design of their own learning activities. This can provide ways to understand the learning practices of the students and at the same time provide digital competence of game design and production with more authentic experiences. The game with the surrounding activities has provided us with a way to look at informal learning practices that improve our understanding of the different aspects of the mobile learning and its outcomes.

5. Discussion

What the surveys, interviews, and self-documented photographs point to is the high value of collaboration between players in the teams and in the workshops. During the summer school course the students' expressed to learn more about technology to extend the game features and viewed the running and problem solving as positive. Being able to participate in designing the game in combination with actually playing the game is described from the interviews as an enjoyable creative challenge for the students. The combination of making up a story and creating tasks for the players is something that the girls say could be used in integrating different school subjects, such as physical education, environmental, math, and science studies. In previous work (Kurti et al., 2008) with mobile outdoor learning activities for students and teacher students they have not been directly involved in the co-design process. Skattjakt has helped to evolve the research by enabling richer evaluation opportunities that can help the design future mobile learning games and learning activities through this involvement. From these nascent results we can see promise in a co-design approach to alleviate some of the challenges faced such as designing activities that take advantage of mobility and context that have value beyond traditional learning and begin to address some of the new literacies afforded by this technology (Lankshear & Knobel, 2006). Skattjakt's game based learning approach integrated with co-design can provide children with powerful opportunities not only to learn through experiences, but also to