Exploring the multiple dimensions of context:
Implications for the design and development of innovative technology-enhanced learning environments
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Abstract

Technology evolution throughout history has initiated many changes in different aspects of human activities. Learning, as one of the most representative human activities has also been subject to these changes. Nowadays, the use of information and communication technologies has considerably changed the way people learn and collaborate. These changes have been accompanied by new approaches to support learning using a wide range of mobile devices, software applications and different communication platforms. In these technology rich landscapes, the notion of context emerges as a crucial component to be considered for the design and technical implementation of technology-enhanced learning environments. The main research question investigated in this thesis relates to the use of different context instantiations for the design and development of innovative technology-enhanced learning environments.

This thesis is a collection of eight papers that describe the results of the research efforts conducted in four different experimental cases during a period of four years. These experiments have been designed and developed as part of two research projects. The theoretical foundations that guided this research were based on the view of context and interaction from a learning theory, human-computer-interaction perspective, as well as dimensional data modelling techniques. Different methodological approaches, (such as action-oriented, design-based research and case study) have been used while investigating the main research question.

The main contribution that this thesis offers to the research community is a conceptual context model accompanied by a dimensional data model that can be used as a design tool for embedding learning activities in context. In the four trials that encompass my empirical work, the conceptual model proposed in the thesis guided the design and technical development of the different novel technology-enhanced learning activities. The outcomes of these efforts provided various insights regarding the use of different context instantiations that have implications for the design and development of these environments.

This thesis advocates that computational context attributes should be used as metadata descriptors that would potentially promote personalization and interoperability of digital learning content. Content personalization offers opportunities for personalized learning that increases learners’ engagement and eventually could lead to better learning results. Furthermore, the research and industrial community could use the context model developed in this thesis as a guiding tool to promote the creation of new ways to personalize services and technologies.

Keywords: technology-enhanced learning, context, context model, contextual metadata
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Table of Contents

Abstract .................................................................................................................................................. III
Acknowledgments .................................................................................................................................... V
Table of Contents ................................................................................................................................. VII
List of figures .......................................................................................................................................... IX
List of tables ........................................................................................................................................... XI

1. Introduction ...................................................................................................................................... 1
1.1 Scope of research enquiry ........................................................................................................... 3
1.2 Purpose .......................................................................................................................................... 4
1.3 Thesis overview ........................................................................................................................... 5
1.4 Definitions ...................................................................................................................................... 6

2. Theoretical foundations .................................................................................................................. 7
2.1 Learning, technology and context ............................................................................................... 8
2.2 Interaction and context: human-computer-interaction perspective ........................................... 9
2.3 Activity Theory ........................................................................................................................... 11
2.4 Context data modelling ............................................................................................................... 12
2.5 Technological implementations to support learning in context: related work ......................... 13
2.6 Summary and initial assumptions ............................................................................................... 14

3. Research problems, activities and objectives ............................................................................... 17
3.1 Research needs ........................................................................................................................... 17
3.2 Research problem ...................................................................................................................... 18
3.3 Research activities and objectives ............................................................................................. 19

4. Methodological considerations ..................................................................................................... 23
4.1 Philosophy of scientific methodologies ..................................................................................... 23
4.2 Action-oriented research ............................................................................................................ 24
4.3 Design-based research ............................................................................................................... 24
4.4 Scenario-based design ............................................................................................................... 24
4.5 Case study .................................................................................................................................... 25
4.6 Methods used ............................................................................................................................. 26

5. Overview of research efforts .......................................................................................................... 29
5.1 MUSIS project: Växjö Library trial ......................................................................................... 29
5.1.1 Paper I .................................................................................................................................... 30
5.1.2 Paper II ................................................................................................................................... 30
5.2 AMULETS project: Bergunda School trial ................................................................................ 31
5.2.1 Paper III .................................................................................................................................. 32
5.3 AMULETS project: Växjö Square trial ................................................................................... 32
5.3.1 Paper IV .................................................................................................................................. 33
5.3.2 Paper V ................................................................................................................................... 34
5.4 AMULETS project: Teacher Students trial .............................................................................. 34
5.4.1 Paper VI .................................................................................................................................. 36
5.4.2 Paper VII .................................................................................................................................. 36
5.5 Summary ...................................................................................................................................... 37
6. Cross-case analysis and research results................................................................. 39
6.1 From context definition to conceptual model......................................................... 40
6.2 From context model to system architecture........................................................... 42
6.3 Dimensional analysis for contextual data model.................................................. 44
6.4 Paper VIII.............................................................................................................. 47
6.5 Summary.................................................................................................................. 47
6.6 Limitations.............................................................................................................. 48

7. Conclusion and future work...................................................................................... 49
7.1 Main contributions................................................................................................. 50
7.2 Future work........................................................................................................... 51

References .................................................................................................................. 53

Collection of papers................................................................................................... 61
List of figures

Figure 1. Dimensions of ubiquitous computing (Lyytinnen and Yoo, 2002) ..................................................2
Figure 2. Thesis organization .........................................................................................................................6
Figure 3. Technology-enhanced learning – domain challenges .....................................................................7
Figure 4. The structure of human activity ....................................................................................................11
Figure 5. Relation between real and conceptual worlds in scientific methods (Dym, 2004) .........................13
Figure 6. The “Ontological gap” metaphor ................................................................................................18
Figure 7. Task – Artifact cycle (Carroll, 2000) ...........................................................................................25
Figure 8. Holistic research on multiple case studies (inspired from Yin, 2003) ..............................................26
Figure 9. Bergunda school trial activities ....................................................................................................31
Figure 10. Växjö square trial activities .........................................................................................................33
Figure 11. Teacher students’ trial activities ...................................................................................................35
Figure 12. Overview of research activities and related publications .............................................................39
Figure 13. Conceptual context model .........................................................................................................40
Figure 14. The technical architecture of the Learning Activity System .........................................................43
Figure 15. Dimensional analysis of context ..................................................................................................44
Figure 16. Context XML Schema ................................................................................................................46
Figure 17. Conceptual scheme for achieving interoperability and reusability of emerging learning objects ...52
List of tables

Table 1. Main research outcomes from four experimental case studies ................................................37
Table 2. Applying the conceptual context model .................................................................................. 41
Table 3. Possible context dimensions .................................................................................................. 45
1. Introduction

Technology evolution throughout history has initiated changes in many aspects of human activities. Human activities typically rely on interactions and communications. The use of information and communication technologies (ICT) has actually changed the way people interact and communicate considerably. Two decades ago the only way to interact and communicate with people was to meet in person, write letters, or use fixed network phones (Schummer and Lukosch, 2007). Today this landscape is completely different, mainly owing to technological innovations. ICT today is present in every aspect of human activities. ICT brings new interaction and communication possibilities to human activities. As a result of this presence and use of ICT, almost all human activities have undergone significant changes. McCarthy and Wright (2004) argue that technology is deeply embedded in our everyday life. Furthermore, they claim we do not just use the technology but we live with it.

From the first vacuum tube computers until today’s highly embedded mobile computers, the pattern of interaction with these devices and their portability has changed dramatically. Initially these patterns of interaction have been described as ‘one-to-many’, multiple users using one computer, thus implying a low level of portability. Thereafter, with the introduction of personal computers this interaction was described as ‘one-to-one’. Computers nowadays have become part of our everyday commodities and have evolved from initially isolated machines to globally interconnected devices (Harper et al., 2008). As a consequence, two new interaction paradigms (‘many-to-one’ and ‘many-to-many’), complemented by an increased level of portability, have been achieved. Portable technology has become a trademark to support new ways of interaction.

Portable technologies have evolved over time, especially mobile phones (as one representative of such technologies), which currently are perceived as more than just a phone; they are now a music player, a radio, a camera, an Internet platform, etc. (Satyanarayanan, 2005; Ballard, 2007). The integration of these different technologies into one device has generated a major shift that is referred to as ‘technological convergence’. According to Bores and colleagues (2003) this convergence is defined as a tendency where ‘different technologies evolve towards performing similar tasks’. The highly converging technological infrastructure in these environments created potential for new computing paradigms (Cooper et al., 2008). This converging technological evolution has generated, as suggested by Milrad (2009), a ‘new mobile landscape’. Technologies in these landscapes offer multiple interaction possibilities and increased mobility support.

Weiser (1993) envisioned these technological landscapes in his pioneering work about pervasive and ubiquitous computing environments. He defined the aim of these environments as: ‘enhancement of computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user’. Lytinnen and Yoo (2002) contributed to this domain by introducing two dimensions of pervasive and ubiquitous computing environments defined as: mobility and embeddedness of the service (Figure 1). The notion of services in this respect is defined as information-based resources accessible with the help of portable technologies.
The mobility dimension is primarily a technical dimension that includes different communication platforms and techniques used to support interaction and communications. The second dimension is service embeddedness, which could be considered as a social dimension.

Ubiquity of the computing environments is directly affected by the way the services offered are embedded in human activities, locations and preferences. Greenfield (2006) describes these environments as ‘everywhere computing’ environments. Ubiquitous computing environments, combined with the possibility that everyone in possession of a mobile device is a content creator, offers numerous possibilities for design and development of ‘value added’ services. The ‘added value’ is typically addressed to the use of different features of user settings for design and development of new services (Kupper, 2005). Information about user location was initially used for design and development of ‘value added’ services. These ‘value added’ services are commonly called location-based services (LBS). Brimicombe and Li (2006) defined LBS as ‘delivery of data and information services where the content of those services is customized to the current or some projected location and context of the user’.

Nowadays, mashups, as one of the key innovations of Web 2.0, allow users to combine data, information services and products from different sources to create new, unique and personalised services (Griffin, 2008). The added value is based on the idea of personalisation (i.e. contextualisation). Contextualisation of the services has become increasingly important mainly owing to numerous resources for capturing context information such as different sensors and actuators, software tools and mobile devices.

The use of these technologies actually initiated a new phase of interaction that could be described as ‘many-to-many’. This engendered numerous changes in the way intellectual human activities are performed. Recent applications of emerging technologies such as NFC (Near Field Communication), RFID (Radio Frequency ID) and different 2D visual codes to support new ways of interaction can be found in many aspects of human activities (such as business (Dutta et al., 2007), healthcare (Chen et al., 2008), sports (Jones and Chung, 2007), entertainment (Graafstra, 2006) and learning (Ogata et al., 2007)).

Throughout history, technology has had a tremendous impact on the way learning takes place (Kravitz, 2004). According to Christensen and colleagues (2008), there is an urgent need to customise learning and information flows. Furthermore, they argue that this need for customisation is based on the fact that ‘each student learns differently’. New technologies enable this customisation, and as a result the notion of technology-enhanced learning has been established. Technology-enhanced learning (TEL) aims at providing socio-technical innovations to support learning practices in a variety of settings. Therefore the field of TEL focuses on the support of any learning activity through
technology (Balacheff, 2006). The potential for using technology in learning activities was advocated a long time ago. In 1922, Thomas Edison predicted that ‘the motion picture is destined to revolutionize our educational system and ... in a few years it will supplant largely, if not entirely, the use of textbooks’ (Dreyfus, 2009). Nowadays many of us spend more time reading/listening with stationary computers, laptops, smartphones, iPods, MP3 players, etc. Beside new interaction, enhanced collaboration and portability, new technologies bring the notion of digital content. Digital content has become a central component in technology-enhanced learning environments. Wiberg (2004, 2007) introduces the concept of ‘learning through networks’ when referring to the latest developments in the interaction society in which IT plays a crucial role.

New technologies offer possibilities for new interactions, user-generated content, and portability that may have an impact on the design of innovative learning environments. Hence, the central topic to be discussed in this dissertation is the exploration of different novel uses of these kinds of technologies (mainly mobile and pervasive ones) to support the design and development of TEL. In this respect, the research presented in this thesis explores different features of mobile collaboration tools and systems to support the customisation of digital content in learning activities. A detailed explanation of these enquiries is provided in the following section.

1.1 Scope of research enquiry

As discussed in the Introduction, technology has impacted on all aspects of human activities. One of the main human activities that has undergone a series of changes is learning. The learning process can be regarded as a social activity based on collaboration (Brown and Duguid, 2000). The purpose of learning is gaining knowledge and knowledge is increased if it is shared. Therefore, interaction and communication can be regarded as the essential components of the learning process. Interaction can be carried out with actors and through artefacts (Hoppe et al., 2005). The actors can be teachers and students while the artefacts can be books, newspapers, computers and other technological devices. Over the years, there have been enormous implementations of technology-enhanced learning environments. These implementations have primarily been guided by different pedagogical approaches mainly rooted in constructivist learning theories. As suggested by Duffy and Cunningham (1996), the main factor in constructive learning could be summarised as when the ‘learner actively constructs knowledge’ in interaction with material systems, discussion with other participants and reflection upon concepts in the specific domain. ICT has been used to help interaction, collaboration, portability and to some extent enhance reflection in technology-enhanced learning environments.

All these technologies and changes have been shaping the evolution of TEL. Initially interaction and communication was direct between students and teachers (i.e. actors). With technology advances this model shifted to become artefact-mediated. Initially, learning systems where collaboration was mediated by computer-based systems only were regarded as eLearning systems. Later, the technology needed to accommodate mobility of the users and hence the collaboration was supported by mobile and wireless technology. This view on technology-enhanced learning was called mLearning. The rapid development of mobile technologies combined with access to content almost everywhere and anytime allows learners to gain new experiences regarding learning in a variety of situations, and not only in school settings. This latest view on technology-enhanced learning supported by wireless technologies and ubiquitous computing is referred to as Ubiquitous Learning or u-learning (Rogers et al., 2005; Syyänen et al., 2005). This learning paradigm is also referred to as Pervasive Learning or p-Learning (Plymale, 2005; Thomas, 2006; Ryu, 2007). In this thesis, u-Learning and p-Learning are considered to complement each other and they will be treated as the same.

Ubiquitous environments create the chance for users to communicate with different computational devices at the same time. The research community refers to these environments as ‘augmented physical spaces’ (Price and Rogers, 2004). These environments have actually moved the interaction behind the traditional ‘desktop’ paradigm, thus offering new possibilities and challenges for design and development of novel interaction modes and ‘value added’ services (Kaptelinin and Czerwinski, 2007), as it is possible to use mobile technologies to support interaction with the real world in a wide variety of settings.
Possibilities for design and development of innovative technology-enhanced learning environments have been driven mainly by technological trends. Nowadays mobile phones and various portable devices are equipped with a number of sensors (such as GPS for location, accelerator, etc.). Under these circumstances, leading industrial companies have started to describe mobile phones as ‘sensor packed devices’ (Nokia, 2008). The trend of blending new functionalities with the mobile phone is based on the idea of embedding more sensors in mobile devices.

Sensors and actuators have actually increased the interaction modes between the users and their surrounding environment. Examples of these interactive spaces can be found in domains such as sports and health care. Actually, many of the leading industrial providers have their own sensor-based mobile companion such as miCoach (www.micoach.com) from Adidas, Nike+ (www.nike.com/nikeplus/) from Nike, Motion Based (www.motionbased.com) from Garmin, Nokia Sports tracker (http://sportstracker.nokia.com/) from Nokia, etc. Use of mobile and sensor-based technologies for fitness purposes has been also investigated in recent research projects such as the Companions Project (Stahl et al., 2008) and Hart Angel (Wylie and Coulton, 2008). In these projects the focus is on the novel use of different technologies and interactive modes (such as audio, video, etc.) in the sports and eHealth domains. Recently, these interactive physical spaces have been developed to augment learning as well. Rogers and Price (2009) enumerate four types of augmented learning activities defined as following: physical exercise games, participatory simulations, field trips and visits, content creation.

Current trends regarding service embeddedness and mobility have increased the importance of context as a notion that may impact on the design and development of ‘value added’ services in different application domains. The explorations described in this thesis are connected with the application of different technologies in learning to the creation of innovative TEL. These efforts are inspired by the numerous challenges that exist in this particular domain. Hoppe (2009) addresses the general issue in technology-enhanced learning domains as a challenge for the integration of different technological resources with the broader educational scenarios. From a technology-centric perspective, these challenges pose a number of interesting questions:

- What features and capabilities should collaborative mobile tools and systems have in order to support the creation of innovative learning activities?
- How do we design and develop a set of mobile applications followed by a flexible architecture that would bridge learning activities across locations?
- How do we create adaptable computational mechanisms that would enable personalisation of the digital learning content and its reusability across different platforms and tools?

Understanding and defining the notion of context in these kinds of learning environments is central in order to be able to address different aspects of these broad challenges. Therefore my research efforts have been geared toward context exploration in order to support the design and development of innovative technology-enhanced learning environments.

1.2 Purpose

The research presented in this thesis focuses on exploring multiple dimensions of context to support the design and development of innovative technology-enhanced learning environments. The use of pervasive and ubiquitous technologies enables innovative design and development of learning environments that are seamlessly integrated with user activities. This integration of learning activities and their high embedding as a result of portable technologies brought about the notion of ‘seamless learning’ (Chan et al., 2006; Seow et al., 2009). Seamless learning implies that learners can learn whenever they are curious in a variety of scenarios and that they can switch between the scenarios easily and quickly using their portable device as mediator (Spikol et al., 2008). According to Sotiriou and colleagues (2006), the aim of seamless learning is to “integrate the use of physical objects that are computationally-augmented and to support and encourage direct interaction between students and virtual objects”. Physical objects and places can be enhanced with the use of different sensors and actuators, thus creating a suitable environment for augmented reality implementations. Augmented
reality offers the possibility to transform the way we entertain and educate by blending digital creations with our view of the world (Bolter and Macintyre, 2007). In these environments, different features of context in which the activity takes place become a crucial factor for generating and deploying ‘value added’ services. Hence, the different approaches to support learning created at the expense of technology are also closely related with the way the context is perceived. Today even industry is making use of augmented reality to provide value added services for mobile users. One such example is the Wikitude AR1 travel guide project that uses Wikipedia digital content to augment physical objects.

Mobile and pervasive technologies available today offer numerous possibilities for context acquisition and may have impact on the way in which technology-enhanced learning environments are designed and developed (Balacheff, 2006). The importance of context in this domain has been advocated by different authors (Sharples et al., 2005; Winters and Price, 2005; Frohberg, 2006). New technologies offer the possibility to use context as an input in the design and development of ‘value added’ functionalities in learning environments. These functionalities are typically deployed with the help of mobile technologies and offer the possibilities for customisation of learning activities. This customisation is usually designed and developed by using different context instantiations (such as location, time, device, etc.). Context affects the way people interact and communicate, and it also affects the learning activity. The main purpose of the research presented in this thesis is to explore the notion of context, its definition and instantiations, representation and modelling for the design and development of technology-enhanced learning environments. Therefore the main question to be discussed in this thesis can be formulated as:

- How can different context instantiations be used as an input for the design and development of innovative technology-enhanced learning environments?

I claim that a proper definition of context is needed in order to be able to elaborate and refine its different instantiations. These instantiations should lead to the integration of different technological resources (applications, digital content, data formats and exchange, etc.) with learning activities. Personalised technologies enable context instantiations, thus providing necessary support for the customisation of learning activities. These technologies offer new possibilities when it comes to interaction that goes behind the ‘desktop paradigm’ and across locations.

In my research I have been investigating these aspects in connection with the design and development of innovative technology-enhanced learning environments. As a result of these efforts, I am suggesting a dimensional context model that could be used as a design and development framework in technology-enhanced learning environments. These findings are presented throughout the different chapters of this thesis. An overview of this dissertation is presented in the following section.

### 1.3 Thesis overview

This thesis is a collection of eight papers (six conference papers, one journal paper and one book chapter). These published papers are appended to this thesis. All these papers have been peer reviewed and have been written as a result of research efforts conducted in four different experimental cases. These experiments have been designed and developed as part of two research projects (MUSIS and AMULETS). A detailed description of the aims and activities of these research projects is given in the chapter three of this thesis.

The theoretical foundations that guided this research are described in the following chapter. This is followed by a discussion of the research plan and objectives. Methodological considerations that were used to make this research operational are described in chapter four. An overview of the research efforts related to four experimental cases with a brief summary of each contributory paper is presented in the following chapter. In chapter six, major results and findings of this research are presented in the form of cross-case analysis. This is followed by a conclusion in chapter seven which discusses the

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major contributions of this thesis combined with my thoughts on future research. Figure 2 attempts to illustrate how the main chapters of this thesis are interconnected. A detailed schematic view of different sections of this thesis and their interconnections is presented in chapter 6.

1.4 Definitions

In this thesis the term ‘technology-enhanced learning’ is used to describe the different views regarding learning supported by technology as described earlier; namely e-learning, m-learning, u-learning, p-learning and seamless learning. The choice of this terminology is inspired by the fact that most of the aspects discussed in this thesis are applicable to some extent to all technology-enhanced learning approaches. Moreover, the use of TEL helps potentially to bypass the binding to single technology when I discuss and explore concepts related to context in TEL environments.

![Figure 2. Thesis organization](image-url)
2. Theoretical foundations

Computer science is commonly defined as the ‘science of information processes and their interactions with the world’ (Denning, 2005). The main question that computer science actually investigates can be summarized as ‘how and what information processes can be effectively automated’ (Denning, 1989). Theoreticians argue that computer science can be categorized as a discipline that belongs to natural sciences, mathematics, engineering and design. Johnson (2001) claims that “whatever field you chose, you would eventually end up doing computing”. Developments in computer science have resulted in major impacts on all other scientific fields. Thus, it can be said that computer science, as a research discipline, includes computing, computing in term of machines, the study of digital information, and interactions with users. The field of research, which focuses on information processing and user interactions with computer and information systems, is typically referred to as research in informatics. According to Tatnal et al., (1995), informatics is defined as “a system comprising hardware, software, people, procedures, and data, integrated with the objective of collecting, storing, processing, transmitting and displaying information”. Adriaans and van Benthem (2008) define informatics more from an interaction perspective, arguing that it is the study of: “the structure of representation and transformation of information by machines, but gradually also by human and various hybrids of the two”. In technology-enhanced learning, different computational issues are typically addressed from a socio-technical perspective (Goodman, 2002). Technology impacts the way people carry out different activities by providing new ways of collaboration, interaction and experiences. Learning, as representative of such activities, has undergone a series of changes as a result of technology usage. Technology-enhanced learning environments consist of humans (i.e. learners) and technology (different tools and resources) and the interactions between them as well as the organizational settings in which learning takes place. Recent research within TEL deals with challenges that can be summarized as: technology and engineering challenges, design and interaction challenges, and learning, social and cognitive challenges (Sharples 2007; Borgman et al., 2008; Milrad, 2009). An attempt to illustrate these challenges is presented in Figure 3.

![Figure 3. Technology-enhanced learning – domain challenges](image)

The activities conducted as a part of this thesis focus primarily on technology and engineering challenges and partially on design and interaction challenges. Nevertheless, the outcomes of these efforts have resulted in learning activities that are closely related to the learning, social and cognitive challenges as well. As suggested by Fischer (1999), technological implementations provide engaging environments for new forms of learning opportunities.

The nature of research in TEL environments implies a multidisciplinary approach. Moreover, a multidisciplinary approach is supported by the fact that there is no unique theory that would fit the
research purposes in the TEL field. Researchers within the TEL field usually recommend a theory-integration approach (Sharples et al., 2005). Balacheff (2006) argues that research on the design, implementation and deployment of technology should be guided by learning theories. Inspired by these ideas, this chapter makes an attempt to integrate different theoretical issues and illustrate how they are related to the main research question discussed in the previous chapter. The specific purpose of this research is related to context instantiations and their use as a design and development input for TEL environments. Thus, the notion of context is the common denominator for theory integration. The theoretical foundations discussed in this chapter are based on the view of context and interaction from a learning theory and human-computer-interaction (HCI) perspective, as well as on dimensional data modelling techniques. A detailed description of these theoretical foundations and the summary of the main assumptions that guided this research are presented in the following sections.

2.1 Learning, technology and context

Theoreticians consider that TEL is a subset of learning (Jonassen and Land, 2000). Despite the changes initiated by the evolution of technology, the aim of learning has always remained the same: to gain knowledge. The Oxford English Dictionary defines learning as “the cognitive process of acquiring skill or knowledge”. Other researchers define learning as a social, intellectual activity that is primarily based on collaboration (Brown and Duguid, 2000). Wenger (2003) defines social learning in terms of social competence and personal experiences. Technology has had a strong impact on the way people learn by providing new ways of collaboration, interaction and experiences.

Numerous TEL approaches have been used to guide developments in this field over the last two decades. Rogers and Price (2009) suggest that to date, most studies about TEL have been “based on or informed by constructivist theories of learning”. These approaches have been mainly inspired by two theoretical perspectives: cognitive constructivism (derived from Piaget’s work (1970) on the theory of knowledge) and social-cultural constructivism (derived from Vygotsky’s work (1978) on cognitive psychology). Moreover, Duffy and Cunningham (1996) suggest that the main component of the constructivist learning theories can be summarized as, the “learner [who] actively constructs knowledge” while interacting with artefacts, discussing issues with other participants and reflecting upon concepts in the specific domain. Bransford and colleagues (1999) complement this view by presenting notions related to effective learning environments. They identify four overlapping approaches: learner-centred, knowledge-centred, assessment-centred, and community-centred. According to Norman and Spohrer (1996), the learner-centred approach focuses on “needs, skills and interest of the learners”. Moreover they compare the “learner centred” approach with the “user-centred” focus of modern interface design. According to Bonk and King’s (1998) view of the learner-centred approach, they define it as: “the learner is at the centre of the learning process and the learning environment needs to reflect this”. Quintana et al., (2006) advocated for the importance of the learner-centred approach in TEL environments, where they referred to this approach as “the challenge for HCI in 21st century”. Hence, this line of argumentation can be summarized as: learning happens in collaboration and learning environments should be oriented towards supporting the users to achieve their tasks. Thus, TEL environments should offer the means for learners to collaborate and provide relevant resources and computational tools to support their learning activities. In this way, the ultimate goal of having a truly “learner centred” approach, can be accomplished.

As a result of the rapid advance of computer technologies and their applicability in learning, a new discipline referred to as computer-supported collaborative learning (CSCL) has emerged (Stahl et al., 2006). This development shows how important technological changes have been (and they continue to be) for supporting learning. Although CSCL refers to computer support for learners, its main principles also remain valid for new, ubiquitous technologies. The CSCL approach promotes the use of technology for collaboration and mediation. Emerging technologies are also bringing new challenges to the CSCL community.

The Horizon Report (2009) identifies six emerging key technologies that may have an impact on learning, such as: mobile, cloud computing, personal web, geo-everything, semantic-aware applications and smart objects. Similar recommendations can be found in the National Science Foundation NSF task force report on cyberlearning (Borgman et al., 2008). Moreover, they emphasize
the importance of digital content by arguing that it will become “as real as paper, lab equipment or textbook”. Mobile and pervasive technologies combined with “recommendation” applications enable learners to identify and use learning resources that appeal to their needs and interests. Thus, technological development increases the possibility for the adoption of “learner-centred approaches” in innovative learning environments.

The most recent projects in TEL exercise the affinity for the adoption of true learner-centred approaches (Sharples et al., 2008). Collaborative technologies, which were used in these projects, facilitated the adoption of a learner-centred approach. The learner-centred approach has been also suggested by Bonk and Cunningham (1998), where they emphasized “the need to anchor learning into real-world or authentic contexts that make learning meaningful and purposeful”. The importance of the context of learning was mentioned by the American Psychological Association (APA, 1997) in their framework regarding learner-centred psychological principles. Context where learning process takes place, in their document is represented as one of the cognitive and metacognitive factors for learning. Learning scientists acknowledge the importance of “learning in context” as one of the situated cognition principles relating to learning environments (Wilson and Myers, 2000). Situated cognition argues that learning is simplified by embedding concepts within the context in which they will be used (Brown and Duguid, 2000).

Barab et al., (2007) advocated the importance of “situative embodiments” for learning activities that take place in authentic settings. Furthermore, they argued that technology provides “associated tools and resources for supporting the situated learning”. Situated learning is a general theory of knowledge acquisition, which is based on the notion that learning (stable, persisting changes in knowledge, skills and behaviours), occurs in the context of activities that typically involve a problem or task, other persons, and an environment or culture (Rogoff, 1991). Within the socially-situated learning perspective (Lave and Wenger, 1991), learning is viewed as an active process of knowledge construction in which learners are typically involved with other learners in authentic, problem-solving situations. Research increasingly indicates that the inability of learners to apply concepts learned in formal contexts is, in many cases, due to the abstraction and decontextualization of the learning (Brown et al., 1989). However, it is not the abstraction of knowledge, as such, that distracts learners, but that the abstractions are not illuminated with contextual examples. Understanding is a product of the context and the activity. Context provides a framework, which guides and supports the learner. In particular, the importance of context information for learning has been pinpointed by Hull (1993), where he suggests: “learning occurs only when learners process new information or knowledge in such a way that it makes sense to them in their frame of reference (their own inner world of memory, experience and response)”.

Success in achieving a learner-centred approach while implementing TEL, is intimately related to the learners’ contextual instantiations. Support for learning activities, which are related to learners’ different contextual instantiations, has become possible with the use of mobile, pervasive and ubiquitous computing tools. These new technologies enable the learning activities to be customised and adopted to particular learners’ needs. Tamminen et al., (2004), suggest that the integration of mobile computational tools, in these highly customisable educational settings, remains a research challenge. In these situations, the notion of context becomes crucial in order to achieve a true learner-centred approach. Considerations regarding a learner’s context offer opportunities to embed learning activities in natural environments (Schwabe and Göth, 2005). This clearly indicates the importance of considering context while designing and implementing effective TEL environments.

In the following sections, the importance of context is described from a technological and an interaction-design perspective.

2.2 Interaction and context: human-computer-interaction perspective

Besides its implication for learning, context is also important for the design of new technologies and especially for new interaction patterns. New technologies (primarily mobile and pervasive ones) offer a lot of possibilities when it comes to new ways of interaction with users or learners (Dourish, 2004).
Thus, from this perspective, it could be said that a central challenge is how to design and develop applications and systems that work seamlessly within a human context. In order to understand this, one must have a well-defined notion of context.

Context has proven to be an important input for the development of interactions, applications and system perspectives (Beyer and Holtzblatt, 1997). However, defining context has been, and still is, a challenge. This challenge can be regarded as how context is perceived. According to Dourish (2004), there are two main ways for defining context: the first one is more technical and the second one is more socially oriented. The technical notion of context, according to Dourish (2004), is perceived as “new way to conceptualize human action and the relationship between that action and computational system”. Current technological landscapes (enhanced by the latest developments) offer new possibilities to conceptualize the relationship functions between human actions and computational systems. According to Ark and Selker (1999), the four most important aspects of pervasive and ubiquitous computing can be summarized as:

- Computing is spread throughout the environment
- Users are mobile
- Information appliances are becoming increasingly available
- Communication is made easier – between individuals, between individuals and things, and between things

Technological evolution (as mentioned in the Introduction) offers multiple ways of employing these above-mentioned aspects, regarding the design and development process of TEL environments. These design and development opportunities are closely related to the notion of context. However, as Ferscha and colleagues (2004) argue, the definition of context in TEL is a perpetual challenge. Different authors have attempted to tackle this challenge by providing numerous definitions of context and different synonymies as well. For example, Hull and colleagues (1997) define context as “aspects of current situation”, which is a very broad definition and slightly aligned toward “social settings”. Another definition is given by Brown (1996), where he defines context as “elements of the user’s environment which the computer knows about”. This definition is clearly representative of more technical-oriented definitions. Another definition is given by Ryan et al., (1997), where they define context as a “user’s location, environment, identity and time”. One of the most-quoted context definitions is provided by Dey and Abowd (1999), where they define it as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”. The importance of the last two definitions is the fact that they actually form the basis for context “conceptualization” (in terms of entities) and do not limit the context information to only “that [which the] computer knows about” (Brown, 1996). In the mobile learning community, the definitions of context slightly differ from those mentioned above, because they perceive the context as a dynamic entity. In Sharples et al., (2005), they describe the notion of context as: “Context should be seen not as a shell that surrounds the learner at a given time and location, but as a dynamic entity, constructed by the interactions between learners and their environment”. In this sense, in the field of mobile learning, context is perceived as a social setting. The important aspect of this definition is that it brings to the context-picture, the notion of “interaction between learners” (i.e. activity). There are many challenges to be faced when dealing with such a diverse set of definitions. The need for understanding context is important for the derivation of grounded design methods while developing TEL environments (Kaenamponpan and O'Neill, 2004). In addition, regarding the development of learning environments, the learners’ activity plays a central role. It is therefore very important to have a proper design and representation of the learners’ activity. According to Dourish (2004), “context and activity are separable”. Learning activity takes place in context, thus it can be said that it is a part of the context. With the help of technology, the possibilities of offering learning content within the context of the activity are increased. From the technical perspective of context, the challenging issue is to find proper information instances to represent the activities. In the following section, Activity Theory (AT) is introduced, and it is one approach used to model human activities (Kaptelinin, 1996).
2.3 Activity Theory

Understanding the role of activity and of context in TEL is an important factor in the design and development of these systems. One of the approaches recommended for analysing human activities is Activity Theory (Nardi, 1996). Activity Theory is a philosophical framework that allows the study of different forms of human practice (Engström, 1987).

Vygotsky (1978) developed the idea that humans interact with their surroundings and that these interactions are mediated through the use of tools and signs. Leontiev (1981) created a hierarchical model for analysing an activity. Engström (1987), inspired by this concept, extended the model to connect it with the subject, the tools, and the outcome, to reflect the collaborative nature of activities that take into account the social aspects of the engagement. Engeström’s activity system can be described as a network of different parameters or elements that influence each other as a framework for the design and development of collaborative learning environments. The structure of human activity (Engström, 1987) is illustrated in Figure 4.

![Figure 4. The structure of human activity](image)

This structure helps to conceptualize human activity and allows us to focus on the context of use (Uden, 2007). Activity Theory provides a framework to instantiate and to understand users’ contextualized activities, providing a simple form to represent concepts such as role, rules, and tools, which have important impacts on users’ activities. Additionally, AT maps the relationships between the elements that it identifies as having influence on human activity (Kaenampornpan and O’Neill, 2005). These relationships and influences are key factors in the design and development of TEL environments.

Activity Theory has been used by different researchers to model human activities in context. Actions are situated in context and they cannot be understood without defining their context (Suchman, 1987). AT provides possibilities to transfer activity into basic units of analysis (Kuutti, 1996). Thus, AT is a valuable tool to use when it comes to the design and development of concept-based learning activities. Wiberg (2001) has used AT as an approach to model work practices. Activity Theory has also been used successfully in designing human-computer interactions for learning activities and more recently has been used in the design of mobile learning (Sharples et al., 2005; Uden, 2007). Finally, applying the AT approach seems to be beneficial when it comes to the description of central HCI notions, which are related to “context”, “situation”, and “practice” (Nardi, 1996).

Since AT provides a framework to instantiate users’ (i.e. learners) activities as a set of simple and standard concepts, it provides also a hierarchical view on human activities. Five basic principles of AT (object-orientedness, hierarchical structure of activity, internalisation/externalisation, tool meditation
and development) identified by Wiberg (2001) could be used as basic conceptual tools for context analysis in TEL environments which I found very relevant for my work.

2.4 Context data modelling

In the previous three sections, the importance of context instantiations for learning activities and interaction was discussed. This discussion was based on learning theories for situated and collaborative learning, contextual design approaches, and Activity Theory. This section develops the discussion towards a computational view and introduces the notion of context data modelling.

Schilit and Theimer (1994) initially defined the notion of “context awareness” from a “location aware” perspective. Other authors discuss broader meanings of context and define awareness as “information and services offered based on the users’ context” (Yang, 2006; Lehikoinen et al., 2007). Moreover, context awareness is closely related to the possibility that its instantiations can be represented as data values, which can be used as events or service triggers. According to Winograd (2001), the development of context-awareness systems requires well-defined context models. Different context models are suggested by researchers, such as Lonsdale and Beale (2004), Brdiczka et al., (2005) and Yang (2006). These developed models usually rely on different contextual. Dimensions used to model context relied upon the categorization provided by Wang (2004), where he identified them as: identity, spatio-temporal, facility, activity, learner and community. Zheng and Yano (2007) propose another categorization of context dimensions defining them as: knowledge potential, social proximity and technical access. This three-dimensional model offers a different abstraction upon the notion of context but it lacks the support for computational mechanisms for context acquisition. Contemporary technologies offer different possibilities regarding context acquisitions, mainly relying on different sensors and actuators. The possibility of representing context as a series of data values is crucial for providing awareness support.

The philosophical foundations for context data modelling can be found in Wittgenstein’s (1922) work about the theory of meaning. The idea of data modelling is rooted in the objectivist tradition, where data is perceived as a mirror or picture of reality (Hirschheim et al., 1995). The idea of mirroring the reality (i.e. mapping) is also known in the human-computer interaction field. In fact, Winograd and Flores (1986) define the process of mapping when they said that “the relevant properties of a domain can be represented by symbol structures”, which computers can process. The idea to define these symbol structures can be based on the notion of dimensional analysis.

Dimensional analysis, as an approach, is commonly used in different scientific disciplines (mainly maths, natural sciences, and engineering) for dimensional modelling. According to Langhaar (1951), dimensional analysis is defined as: “a method by which we deduct information about a phenomenon from a single premise that the phenomenon can be described by dimensionally correct equations among certain variables”.

According to Vignaux (1991), the basic idea behind dimensional analysis is to create models, based on identifiable dimensions, in order to develop an analytical tool to simplify complex phenomena. In the scope of this thesis, learning in technology-enhanced environments can be seen as complex phenomenon (Bar-Yam, 2005). Context, in TEL, can be understood as complex phenomena and therefore, dimensional analysis can be used as a tool for modelling. According to Dym (2004), modelling is “an activity, a cognitive activity in which we think about and make models to describe how devices or objects of interest behave”. Therefore, the main idea behind models is to ease the understanding of complex phenomena. This simplification would potentially enable the development of context representation as a “symbol structure” that can be processed by computers. Therefore context dimensional modelling could be beneficial for identifying different context instantiations that could be processed by computers.

The heterogeneity in the definitions of context illustrates its complexity; therefore, the creation of a model would potentially be beneficial. The link between the “real world” and the “conceptual world” is based primarily on models (Dym, 2004). This interconnection is illustrated in Figure 5.
Context is a real world phenomenon that needs to be understood when providing support for context awareness. Observations in TEL can lead towards new definitions of context. These definitions, supported by dimensional analysis, could potentially create new models of context. The model could also offer possibilities for data representation. Lonsdale and Beale (2004) put forward one such model suggesting that the object view on context, and its use, as metadata. Lehikoinen et al., (2007) also advocated the use of context as metadata. Furthermore, they argued that context, as metadata, could be a way forward to offering "value added" services.

The notion of "value added" services is closely related to the notion of context awareness. Different instantiations of the users’ context (that are retrievable by means of sensors and actuators) could be used as event or service triggers, thus enabling the deployment of "value added" services.

Overall, the process of modelling context should facilitate its understanding. The model should detail the conceptualization and context acquisition. Contemporary technologies offer new, more powerful resources for context acquisition. Different sensors and mobile devices are potential generators of context data (Campbell et al., 2008); they are useful as design and development tools for new “value added” services. The field of TEL can have substantial gains for new technologies, which would enable instances of users’ context becoming a part of the design and development process. This corresponds with the contextual design approach, where the design process of a system or artefact is guided by the context of the intended user (Beyer and Holtzblatt, 1997). Numerous prototype implementations in TEL, which make use of different context instantiations for their design and development process, are described in the following section.

### 2.5 Technological implementations to support learning in context: related work

Recently, there have been numerous approaches and prototype implementations in TEL environments that make use of different context instantiations. Initially, information about learners’ locations as a context instantiation was used for the development of “value added” services in TEL environments. Benford (2005) suggested that use of location-based services (LBS) in educational settings would offer advantages such as tailoring educational content to a specific location/object, thus contextually increasing relevancy. Furthermore, he suggested that this would potentially lead toward personalized learning experiences. These features of LBS have been recently explored in problem-solving learning activities and in educational games. Nova et al., (2005) suggested that location information could be used as a tracing device to supporting collaboration or as an event trigger. The use of tracing devices (GPS) can be found in a location-based game, called Savanna (Facer et al., 2004). The Savannah game explores how positioning technologies are integrated into the physical environment to explore animal behaviour in Africa, by providing students with the ability to recreate and experience animal life in outdoor settings. Another example, regarding the use of contextual ubiquitous technologies, is in an ecological outdoor-learning environment, developed by Rogers et al., (2005). The main idea of the
Ambient Wood project was to design and use new forms of digital argumentation for learning about woodlands in field studies, incorporating the learning-context attributes, which relate to the environment and location. Contextual services have also been developed and implemented by Ogata and Yano (2004) to support collaborative learning activities in ubiquitous computing environments in the context of the TANGO (Tag Added learNinG Objects) project. This system provides learners with tagged-based information about the objects in their surroundings, based on the learners’ profiles and using the context-based attributes of the location and the environment.

The importance of context and new interaction technologies in learning was suggested by Schmidt and Braun (2006), where they introduced the notion of “context-steered learning”. Furthermore, they suggested that possibilities for observation of the learners’ activities are crucial for system awareness and content recommendation. El-Bishouty and colleagues (2007), in their project PERKAM (PERsonalized Knowledge Awareness Map), explored the notions related to the learners’ profile. With the use of a ubiquitous computing environment, they enabled learners to share knowledge, interact, collaborate, and exchange individual experiences.

Different uses of context instantiations can be found in projects described by Sharples et al., (2008). In these projects there is a clear tendency to develop a seamless integration of technologies in a variety of educational settings, such as museums, field trips etc. These concepts are complemented in the findings of Kukulska-Hulme et al., (2009), where they identified context as central construct for the development of TEL environments. In one recent research effort conducted by Hansen and Bouvin (2009), the HyCon framework for handling context in a mobile learning environment, is presented. Furthermore, they suggested the classification of context into three specific domains, namely: physical, digital, and conceptual.

In all these TEL projects, there is a strong emphasis on context instantiations and the use of new technologies to support situated and collaborative learning activities. New interaction modes and “value added” services emerged as a result of new technologies and were based on user locations, activities or profiles. On analysis, it can be seen that these TEL projects began with a single and isolated contextual instantiation and, after they evolved, they moved towards more complex approaches of defining context (using multiple instantiations). Where there are many possibilities for retrieving different attributes of context, complex approaches for defining and modelling context are appropriate for designing and developing TEL environments.

2.6 Summary and initial assumptions

Technology enhanced learning is a relatively new field of research, which is continually evolving at the expense of new approaches in technology usage and design. Beside the fact that TEL relies on technology development, other fields also influence it, mainly due to its multidisciplinary nature. The theoretical aspects described in this chapter present an integrated approach for discussing issues related to context in TEL.

Theory offers the guidelines for design, implementation and evaluation. Moreover, practice results are used to revise and refine theories. In TEL, this process is very important and challenging, mainly due to the multidisciplinary nature of the field. A major challenge is to find synergy factors, which could combine the different theories that lead to design, implementation and practice. The synergy factor identified in this thesis has been the notion of context. Context is a relevant factor in learning theories, in computational theories, and in design theories. Despite the fact that the research illustrated in this thesis is aligned towards technological development and computation, the use of other complementary theories is eminent. Research described in this thesis has led to the adoption of a number of assumptions and definitions that have been central to the work.

Learning, as complex phenomena (Levonen et al., 2003) is closely related to humans’ psychological and cognitive apparatus. The main assumptions derived from a learning-science perspective, which formed a framework for the practice in this thesis, are:
A1: Learning, with help of personalized technologies, can be perceived as a learner-centred approach. (Leadbetter, 2005)

A2: Collaborative technologies enable the learning process to be situated and collaborative. (Spikol et al., 2008)

The use of pervasive and ubiquitous technologies brings numerous challenges when it comes to interaction and communications among users. These technologies enable better context acquisition and thus different contextual instances can be used as a design and development input.

A3: Interaction behind “desktop paradigm” and learning behind “classroom settings” is possible with the use of advance technologies (mainly pervasive and ubiquitous ones) (Rogers and Price, 2009)

A4: Activity is a part of context. There is a need for methods and models to dissect this complex social construct into design and development inputs. (Kuutti, 1996; Nardi, 1996)

A5: Defining context still remains a challenge. There is still a need for methods, models and new tools for context acquisition. (Dey et al., 2001; Winograd, 2001)

A6: The notion of “value added” services is closely related to context awareness. Modelling context attributes would enable content adaptation and reusability, thus offering possibilities for “value added” services. (Specht and Kravcik, 2006; Lehikoinen et al., 2007)

Based on the theoretical foundations described in this chapter and guided by the assumptions presented above, the following chapter describes specific research questions that were investigated in this dissertation.
3. Research problems, activities and objectives

3.1 Research needs

The rich technological landscape, in which we live in, enables us to use different devices to deploy, invoke, and represent services that are related to our everyday context. In his book, “The invisible computer”, Norman (1999) defined the design challenges in ubiquitous computing environments, saying that we need to: “Design the tool to fit the task so well that the tool becomes a part of the task, feeling like a natural extension of the person”. Nowadays, mobile devices are no longer perceived as distinct electronic artefacts, but more as personal digital companions in our everyday activities.

This constantly-changing landscape brings numerous design and development challenges for researchers and practitioners in the TEL community. As a result of these trends and increasing research needs, a large number of scientific conferences, journals and networks of excellence have been established. Members of the research community, who participate in these activities, are focusing their efforts on the use of new technologies for the design and development of innovative learning environments. Moreover, at a political level, the European Union (EU) has advocated the importance of ICT and learning in their Lisbon Strategy and in the key actions of the Seventh Framework Programme (2007-2013).2

The aim of the first designers of computer-based information systems was to define novel ways of interaction and use (Langefors, 1966). Computer-based systems are mainly used for production, processing and transmission of information and services. Initially, the cost for producing information was rather high and, as time passed, this cost was radically reduced, mainly due to the rapid development of hardware and software. In the current technological landscape, one of the main research challenges is related to the possibility of increasing the “value” of information, thus paving the way for the creation of “value added” services (Davis et al., 2006). Here, the value of information is related to its relevancy for the users. Nowadays, with the technical possibilities offered by mobile devices, different attributes of the users’ context can be retrieved using sensors and actuators. Cooper and colleagues (2008) refer to these developments as “new computational paradigms” that have actually changed “the conception about what is computable”.

Similar challenges are also faced in the field of TEL. The current technological landscape offers different possibilities when it comes to supported learning and teaching. In this field, new computational paradigms offer novel possibilities for interaction and communication that go behind the desktop paradigm and the traditional use of computers in classroom settings.

The current technological development of mobile computing and wireless networking capabilities enable users to overcome the drawbacks of desktop computing (Cheok et al., 2006). Hence, one particular direction of research explored in this thesis investigates the options for the seamless integration of technology to support learning activities. The possibilities that new technologies bring into the TEL domain enable us to develop new perspectives in order to tackle different issues in the field. Balacheff (2006) and Hoppe (2009) have identified a number of technical research issues in the field of TEL that can be enumerated as follows:

- Implementable models of context-as-construct
- Technologies to support interactive modalities of TEL (collaborative, mobile and inquiry learning)
- Device heterogeneity, technical integration and system architectures
- Highly realistic and interactive simulations to support informal learning

2 http://ec.europa.eu/information_society/tl/edutra/index_en.htm
Technology-enhanced innovative authoring and learning systems

This set of technical research issues in the field of TEL has been formalized in the specific research question that has been investigated in this dissertation.

3.2 Research problem

An attempt to illustrate the interaction challenges related to the design of computer-based information systems and users is presented in Figure 6. We refer to this challenge as “ontological gap” metaphor. Within the HCI field, authors refer to interaction challenges as “usage scenarios” or “task analysis” (Kaindl and Jezek, 2002). In this thesis, the choice of metaphor “ontology gap” was inspired by work conducted by Gruber (1995), where he defines ontology as: “specification of conceptualization”. The ontological gap represents the gap that exists between users and their interactions in computer-based information systems. Exploring different computational instances that would lead to new ways of interactions could be used to bridge this gap. Schmidt and colleagues (1999), argue that context is a key issue in “interaction between human and computer”. Identifying different instances of context could enable us to enhance interactions, design and enhance the development of “value added” services, resulting in increased relevancy for the users.

In Figure 6, the ontological gap metaphor represents one path with two possible directions. The first direction relates the information (i.e. content) and interactions to the user’s current context. The second direction educates/trains users to make better use of the information and interaction possibilities that are offered by computer systems. Current developments in ICT offer extensive possibilities to support new interactions between users and computer-based systems. Dix and colleagues (2004), refer to these technological trends as “continuous interaction”, which have shifted computing from a “localized tool to a constant presence”. Identification of different instantiations of context and using them as ways of designing and developing new systems, could potentially increase the way they can adapt the applications and systems that have been developed. Dix and colleagues (2004) defined “appropriate physical interaction experience” as one of the main interaction challenges in ubiquitous computing environments. The current technological landscape enables users (i.e. learners) to have better access to content and services. These technological trends have affected the TEL field and as a result, numerous challenges (as enumerated in the previous section) have emerged, especially when it comes to the embodiment of learning activities in these environments. In this thesis, the focus will be on the different possibilities of using contextual instantiations to seamlessly integrate technological tools and applications in innovative learning environments.

According to Hansmann et al., (2003), the principles of pervasive/ubiquitous computing are: decentralization, diversification, connectivity and simplicity. These principles imply the mobility of users, heterogeneous device environments, and higher usability and hence, usage in the learning domain opens opportunities for new interaction and collaboration patterns. New interaction and collaboration patterns that emerge as a result of using pervasive technologies, present a powerful tool

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3 The term is borrowed from philosophy where according to Michael Silberstein, it defines the gap between fundamental ingredients/parts of reality that are not conscious (such as particles and fields) and beings/wholes (such as ourselves) that are conscious (Freeman, 2001).
for bridging the *ontological gap*, presented earlier. These technologies offer possibilities for providing services and information that are more relevant for the users in their current situations. As Garlan and colleagues (2002) suggested, “the most precious resource in a computer system is no longer its processor, memory, disk, or network, but rather human attention”. The users’ context becomes a central notion in these environments.

The research presented in this thesis, addresses issues relating to the new interaction and communication possibilities emerging as a result of using context instantiations for design and development of TEL activities. Moreover, this thesis explores new opportunities and challenges for the design and development of TEL environments, using mobile and ubiquitous computing together with positioning and sensor technologies. In the past, the use of context instantiations became a research approach for narrowing the *ontological gap*. Defining and making use of context instances represents a technical challenge since it requires multiple data-capturing technologies and modelling techniques. With the help of pervasive and ubiquitous technologies, new possibilities for bringing computational support into the context of human activities have emerged (Zheng and Yano, 2007). A remaining challenge in the TEL environment continues to be the seamless integration of mobile context-aware computing services in these new settings (Tamminen et al., 2004; Hensen and Bouvin, 2009). Therefore, in these rich, technological environments, the bridge of the *ontological gap*, using different context instantiations, becomes both a design and a development challenge. The research described in this thesis primarily examines these issues in relation to the TEL environment. As a result, the main research question to be investigated in this thesis is formulated as follows:

- How can different context instantiations be used as an input for the design and development of innovative, technology-enhanced learning environments?

While trying to answer this question, another set of more specific research sub-questions has been identified. These two sub-questions are:

- How can context be conceptualized in a set of simple attributes (features) that could be used for guiding the design and development process?

and

- What are the benefits of using computational context attributes (features) as design and development instances for innovative TEL environments?

### 3.3 Research activities and objectives

Research activities, conducted as a part of this thesis, have focused primarily on technology and engineering challenges and partially on design and interaction challenges within the TEL domain. The different activities that were carried out as a part of this research consisted of:

- Literature review
- Conceptual design
- Technological development
- Pilot experiments with users/learners
- Evaluation

This research has been closely related to two research projects, namely: Multicast Services and Information, in Sweden (MUSIS) and Advance Mobile Ubiquitous Learning Environments for Teachers and Students (AMULETS). The MUSIS project brought together Sweden’s TeliaSonera, Växjö University, Luleå University of Technology/CDT, e-Centret, the City of Stockholm, and Bamboo MediaCasting, a company pioneering the field of cellular multicasting. The MUSIS project was partially funded by governmental bodies – Swedish Vinnova and Israel’s Matimop – as part of the Sweden Israel Testbed Programme (SIBED) programme, a joint Swedish–Israeli mobile technology research effort. The MUSIS project was designed to explore, identify and develop a number of innovative mobile services with rich multimedia content to be distributed over wireless networks in
university campuses. A variety of content, organized in channels, was distributed to the students. The content included general media such as music video, radio clips, and news feeds, and also campus-specific information such as reminders and announcements of changes in the class schedule, summaries of lectures (in audio and video format), and preparatory notes for upcoming sessions. The campus-specific content was mostly produced by teachers and, in some cases, by the students themselves. Research activities, carried out as a part of the research presented in this thesis, were oriented towards exploration of the notion of context and its use as a design and development input.

The AMULETS project is a thematic effort established as a part of the Young Communication program, which is designed to boost the digital competence among teachers. It is partially funded by the Knowledge Foundation and it is a collaborative project with partners from the Blekinge Institute of Technology, Kalmar University and Växjö University, with Växjö as the coordinating university. AMULETS has been designed to explore how teachers can develop and implement novel educational scenarios combining outdoors and indoors activities using ubiquitous computing technologies together with stationary computers. Indoor and outdoor activities were enhanced with different, new technologies and devices such as Smartphones, personal digital assistants (PDAs), sensors and actuators. A set of software applications, developed as a part of this project, were tested in the fields of natural science, history and geography. As a part of this ongoing project, three experimental case studies were designed and implemented, where different context instantiations were used to integrate learning activities in authentic settings.

As part of this research, four specific objectives were defined in connection to the MUSIS and AMULETS projects according to following:

1. To explore different notions of context in the TEL field and how they can be instantiated to support learning.
2. To design and develop prototype implementations based on the notion of context instantiations (retrievable by use of different sensors and actuators).
3. To explore new interaction and collaboration modes between learners that may emerge with the application of these new technologies and tools.
4. To model context as a set of dimensions that can be used for the development of a metadata scheme to support content reusability.

As a result of these activities, eight papers were published and are appended to this dissertation. These publications investigated different aspects and perspectives of the research question and its objectives. Details about the contribution of each one of these publications are provided in Chapters 5 and 6. According to the evolution of this research, these publications are categorized in relation to the different stages of my research, namely: exploration stage, design and technical development stage and analytical and reflective stage. The exploration stage was basically the initial year of my doctoral studies and it involved different research activities such as; literature review and initial conceptual design ideas. In the design and technological development stage, research activities have been mainly related to conceptual design, technological development and piloting with users. In the reflective and analytical stage, research activities mainly consisted on analysis of results, elaboration of findings and discussions. A list with a detailed description of all these publications can be found below.

**Exploration papers:**


Design and Technical Development papers:


Analytical and Reflective papers:


4. Methodological considerations

This chapter discusses methodology and starts by presenting fundamental issues relating to the importance of selecting the right scientific methodologies and their relevance for the validity of research. Thereafter, it introduces different empirical-based approaches and methods that are relevant for the type of research discussed in this thesis. This chapter concludes with a description of the methods used to conduct this research.

4.1 Philosophy of scientific methodologies

The scientific community has done considerable work to justify its scientific research by defining and developing different scientific methodologies. The English philosopher, Roger Bacon is usually credited as the founder and developer of scientific research methods (Marczyk et al., 2005). Furthermore, Francis Bacon and René Descartes provided a major contribution in scientific method development. Francis Bacon’s work (1620) on scientific methodology, based on the book, “Novum Organum” is widely considered as an initiator of the inductive approaches (or what is now known as the empirical perspective). René Descartes’ work (1637), “Discourse on Method”, is considered an initiator of the deductive approaches (or what is today mainly referred to as the analytical perspective). Despite having their differences (especially in their reasoning procedures), these two approaches are presented as complementary approaches in the Wallace model of research processes, as described by Järvinen (2004).

In more recent work, there is a more practice-oriented definition of scientific methodologies. For example, Kazdin (2003) defines methodology as: “principles, procedures, and practices that govern research”. A goal-oriented definition of scientific methods is provided by Cozby (1993), where he claims that the main benefit of the scientific method is to “provides a set of clear and agreed upon guidelines for gathering, evaluating, and reporting information in the context of a research study”. Despite the different efforts, there is still disagreement among researchers about the elements that comprise a reliable scientific method. However, as Marczyk and his colleagues (2005) suggest, most generally-agreed elements of scientific methods within a research community are: “an empirical approach, observations, questions, hypotheses, experiments, analyses, conclusions, and replication”.

Each of these elements of the scientific method is very important and affects the type of research approach used. Different authors (Creswell, 2003; Marczyk et al., 2005; Schwab, 2005) define two broad categories of research approaches: quantitative and qualitative. These categories can also be linked to Bacon’s initial scientific methodology thoughts (more quantitative-oriented) and of Decartes (more qualitative-oriented). Qualitative and quantitative research methods can also be differentiated by the nature of the variables measured during research. Anderson (1961) identified two categories of data: metric and non-metric data. Among members of the scientific community, metric data is often referred to as quantitative data while non-metric data is referred as qualitative data (Hair et al., 1995). These ideas and definitions regarding scientific methods have influenced the research presented in this thesis.

The choice of methodology has been fundamentally influenced by the above-mentioned studies on scientific research. Research in TEL has socio-technical aspects and is often guided by design, implementation and practice. This research deals with the innovative use and development of TEL environment, thus a more qualitative method was used. The choice of qualitative method was affected by the nature of some of the research investigations, such as patterns of adopting new technologies, design issues etc. Nevertheless, some quantitative instruments were also used. The research activities described in this thesis were influenced by researcher participation and involvement, meaning that an action-oriented approach was used. Within this process, a number of other methods were used to bridge theory and practice. These methods were design-based research (DBR collective, 2003), scenario-based design (Carroll, 2000), and case studies (Yin, 2003). These approaches, and the ways they were used, are presented in the following sections.
4.2 Action-oriented research

Action research is considered a qualitative method that is characterized by two main features: researcher’s participation and refinement of theories. The main aim of the action research approach, according to Holter and Schwartz-Barcott (1993), is to bridge the gaps between theory, research, and practice. According to Denscombe (2007), action-oriented research deals with practical issues and deals with problems that “arise as a routine part of activity ‘in the real world’”. The research described in this thesis deals with contemporary issues and problems related to the TEL field, thus an action-oriented approach seems to be suitable for this purpose. Moreover, the process that is usually affiliated with action-oriented research has attributes of practice, iteration and participation. In this research, practice was constructed in the form of case studies, typically led by design aspects and socio-technical system implementation (Susman and Evered, 1978; Denscombe, 2007).

The iteration attribute of action-oriented research is typically associated with cyclic approaches, where theory guides the practice and practice results imply the theory modifications. Different researchers illustrate this iteration process with cycles comprising different stages. (Riding et al., 1995; Denscombe, 2007).

Despite the fact that participation is regarded as one of the main attributes of action-oriented research, it has also been the subject of controversy among researchers. For example, Denscombe (2007) says that participation “limits the scope and scale of the research” and Susman and Evered (1978) consider impartiality as the main disadvantage of participation. On the other hand, participation provides the opportunity for self-development, thus implying the notion of “learning-by-doing”, as identified by the action-oriented approach. Due to the nature of a selected research problem, the use of the action-oriented approach seems a reasonable methodological choice because it offers the possibility for active participation while testing different innovative technologies and software tools.

4.3 Design-based research

Balacheff (2006) suggested that the design and development of technological support for authentic learning activities requires new design frameworks and practices. In recent years, educational researchers have given increased attention to research questions and aspects that may influence practice. The importance of practice and innovations in design and development of TEL environments is evident, mainly due to the need for novel ways of technological integration within learning activities. The design of these innovative environments requires direct participation, thus design activities have become a part of research activities (Edelson, 2002). These efforts include, among others things, the design of educational activities and software tools, stakeholder actions, and involvement in different processes. This approach to research, characterized by iterative design and formative research in complex real-world settings, has been referred to as design experiments (Brown, 1992), developmental research (Richey et al., 2003), and lately as design-based research (DBR collective, 2003). 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 (Hoadley, 2004). Design-based research (as a participatory approach) follows an iterative cycle of designing, implementing, analysing and modifying. As Barab and Squire (2004) state: “DBR is a series of approaches with the intent of producing new theories, artefact and practices that account for and potentially impact learning and teaching in naturalistic settings”. Design-based research offers the flexibility to enable innovations to be designed and developed. Innovative uses of new technologies were used through different stages of this research. They were connected to the design and development of innovative TEL environments and were inspired, conceived and implemented by the ideas and rationale suggested by this methodology.

4.4 Scenario-based design

Another participatory approach, which is typically used in the design and development of socio-technical systems, is scenario-based research. Carroll (2000) defined scenario-based design as an approach that “seeks to exploit the complexity and fluidity of design by trying to learn more about the structure and dynamics of the problem, trying to see the situation in many different ways, and interacting intimately with concrete elements of the situation”. Furthermore, Dix and colleagues
(2004) advocated the use of scenarios for human-computer interaction (HCI) research by defining them as “rich stories of interaction”. The use of scenarios is a useful approach because reasoning can be developed for situations even before they have arisen. This is used in order to try and see a design situation in different ways, and to intimately interact with its concrete elements. The possibility to describe different types of interactions in a scenario is crucial to the design process, since it enables the researcher to identify the best ways for the integration of technological tools to support human activities. Based on Carroll’s recommendations, scenarios should have the following characteristics: setting, actors, goals or objectives, and actions and events. Scenario-based design enables the investigation of multiple views of interaction between the users and the information system, and interactions between the users themselves are mediated by the system. Typically, scenarios are used to define the requirement of the system, while the artefact produced as a result, provides new possibilities. This aspect of scenario-based design is typically illustrated with a task–artefact cycle (Figure 7).

![Figure 7. Task–Artifact cycle (Carroll, 2000)](image)

Due to above-mentioned characteristics, scenarios can provide a framework for a design-based science of HClIs. Scenarios are used for identifying needs and establishing requirements (Preece et al., 2002) and also as a resource that can be used and reused throughout the design process (Dix et al., 2004). Scenarios are used to suggest how the users will deal with potential design solutions, to test the validity of implementation, and as a base for providing test cases for final evaluation. Carroll and Rosson (2005) argue that scenarios in TEL can be very productive, especially for the design and development of learning activities in authentic settings. With reference to the above-mentioned features of the scenario-based design approach, it represents a valuable resource for the design of the different cases investigated and presented throughout this research.

4.5 Case study

Schramm (1971) defines the essence of case study research as an approach that “tries to illuminate a decision or set of decisions” related to the problem domain. This is typically attributed to practice, implementation, and results. According to Yin (2003), the case study is defined as: “an empirical study that investigates contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. The contemporary nature of the case study, combined with its practice and action-oriented approach, fits well the purpose of this research study because of the research objectives, presented in Chapter 3. Using the case study as a research strategy can be categorized according to the type of questions asked and eventual control imposed on the research settings. Based on this categorization (proposed by Yin, 2003), the research strategy, which deals with questions, such as “How and Why” and, which require control over “behavioural events” and, which has a “contemporary” focus, is regarded as being an experiment. Experiments used as a case-study strategy, offer the researcher the possibility of having full control over the activities under investigation. With regard to the features presented above, the case study is a qualitative research method and, to some extent, is associated with an action-based approach and a scenario-based design. This characteristic of the case-study approach was very beneficial for the research described in this thesis, since it was used as a catalyst for integrating different methods to achieve a useful approach.
4.6 Methods used

The research carried out in this thesis consisted of literature reviews, empirical activities, conceptual design, technical development practices, prototyping with users, and evaluation. According to Denning’s categorization (2005), practice is more an attribute of art than science. Bruno Latour (1988), in his famous book, *Science in Action*, introduces the notion “science-in-making”. Furthermore, he argues that much of the “science-in-making actually appears as art until it becomes a settled science”. Moreover, Latour argues that science-in-the making is actually a process by which scientific facts are proposed, argued, and accepted. This process usually goes through an iterative cycle of practice, improvements and theory creations. The research presented in this thesis contains all these attributes. It has been conducted on four case study experiments over a three-year period. According to Yin (2003), a case-study research strategy can be employed multiple times and in the same problem domain. To explain this approach he proposes a 2x2 matrix, where he suggests that case studies can be either holistic (with a single unit of analysis) or embedded (with multiple units of analysis). Yin’s matrix has been adopted and applied in this research, resulting in the graphical representation illustrated in Figure 8. Research activities that are part of this dissertation have been designed as multiple case-study experiments (four of them) and a holistic perspective was employed for their analysis. Therefore, this research approach can be placed in the upper-right quadrant of Yin’s matrix.

![Figure 8. Holistic research on multiple case studies (inspired from Yin, 2003)](image)

Each one of the predefined experimental activities was inspired by ideas and guidelines from design-based research and scenario-based design.

Design based research was also used since it provides the means for blending of empirical research and practice with theory driven design. Collins and colleagues (2004) suggest that design experiments can be conceived as “formative evaluation strategy”. Furthermore, they suggest that educational innovations must carry out both qualitative and quantitative assessments. Formative assessment in the scope of this thesis could be regarded as the iterative way of design for all experimental case studies. Lessons learned from each one of these experiments were used as inputs for the next iterations (experiments). The iteration process was inspired by an action-oriented approach and each trial was a cycle of this iteration spiral.

Despite the use of qualitative research methods, there was a need for certain measurements when it came to the formalization of context instantiations. Thus, there was also a need to rely on some quantitative tools. According to Marczyk et al., (2005), the main characteristic of a quantitative
research approach is “formal and systematic measurement”. The use of quantitative tools was very important in the explorative phase of this research, where numerous quantitative approaches were tested. During the design and technical development phases, the focus shifted toward a qualitative research approach. In the last phase of this research, qualitative and quantitative methods were used. The reason for this mixed-method approach is attributed to the social-technical nature of the field of TEL, relating to design and engineering challenges. Creswell (2003) and Denscombe (2007) referred to the combined use of qualitative and quantitative research methods as mixed methods. Creswell (2003) suggested that use of such an approach was beneficial, especially in the domain of complex systems and human-computer interaction.

During the different research activities conducted in the last four years, my role as a researcher has evolved over time. From initially having the role of a facilitator and a mediator (during the preparation stages of each of the experimental cases), my role changed towards being an observer (during the experimental trials). Finally, in the reflection and analysis stage of my work, I had a more analytical role.

An overview of the research activities and their results and methods used are presented in the following chapters. Thus, the main results of this research have been strongly influenced by an empirical base created during these four iteration cycles (case study experiments).
5. Overview of research efforts

The research efforts to be presented in this chapter are closely related to the objectives discussed in chapter 3. Four experimental case studies as a part of the MUSIS and AMULETS projects have been designed, developed and carried out. The aim of these experimental cases studies was to explore the importance of context and its implication for the design and implementation of novel TEL environments and activities that rely on the use of mobile and ubiquitous technologies. This exploration process was carried on by developing a number of prototype implementations that were devised based on the utilization of different context instantiations. The efforts discussed in this chapter could be analyzed as belonging to three different stages of my research namely; exploration stage, design and technical development stage and reflective and analytical stage. The exploration stage was basically conducted as a part of first experimental case study where different notions of context have been explored and investigated. The next two experimental cases represent the evolution of some of the ideas generated in stage one towards a design and technical development phase where a variety of innovative technological solutions have been adopted to support learning in different settings. The third and final stage can be characterized by reflection and analysis where the focus has been in a cross-case examination based on the activities and results from stages one and two. The publications appended to this thesis have been categorized according to these different development stages. Several research explorations and questions have been investigated during this entire process, as described below:

- Exploring the notion of context in technology enhanced learning environments. (Paper I, II and VIII)
- How can different context attributes be used to guide the design and implementation of technology-enhanced environments that promote innovative learning activities? (Paper III, IV, V and VI)
- Which are the new collaboration and interaction patterns that may arise as a consequence of learning in this new kind of technology enhanced environments? (Paper VI and VII)
- How can context be conceptualized and modeled in a set of simple computational instantiations (features) that could be used for guiding the design and development process of novel learning activities and resources? (Paper VI, VII, VIII)

In the following sections of this chapter, the details of each experimental case study are presented accompanied by a summary of each one of the contributing papers to this thesis. In the rest of this thesis and for simplicity purposes only, the term “experimental case studies” is referred as trials and they are presented in chronological order.

5.1 MUSIS project: Växjö Library trial

This trial was conducted over a period of four weeks during October-November 2005. In this trial, ten librarians at Växjö Public library were equipped with Nokia 6630 smart phones with GPRS access to the MUSIS channels (including text, audio and video material). The aim of this trial was to conduct an initial exploration with regard to the notion of context and its possibilities to affect the design and development of TEL environments. For the purpose of this trial, one assumption is that librarians are not considered only to be knowledge workers but they can also be perceived as learners (Milrad et al., 1999). The results of this initial exploration were mainly based on the analysis of empirical data collected during this trial. Different data gathering techniques have been used in order to identify potential contextual attributes of the librarians working settings. The main idea was to explore how these features could be used as a design and a development input for the design and implementation of a new mobile service. Questionnaires’ with participants have been conducted in the first and last day of the trial while interviews have been conducted two weeks after the start of the trial. Based on results from the questionnaires, interviews and observations, it was apparent that librarians spend most of their time at work providing information regarding the content of the books to users. Guided from this fact, a prototype of an audio book review mobile service was developed after two weeks from the
beginning of the trial. This service enabled librarians to share with fellow colleagues their impressions regarding new books, thus enabling better services for library users. The audio content (created by one of the librarians) was multicast to other librarians, using the MUSIS infrastructure. The contextual attribute identified here was related to the librarians’ daily activity. In the questionnaire conducted at the last day of the trial, librarians were positive about the audio book reviews service. Seven librarians thought that the audio clips with the book reviews would be very interesting and useful but they needed more time in order to further explore these ideas. One participant was so positive that wished that such a service could be introduced within a year, while another questioned the librarians' ability to find time and resources to produce the digital content for this type of new service.

Two scientific conference papers that describe the activities and findings that emerged from this trial have been published. These two papers (I and II) are appended to this thesis while a short summary of each of them is presented in the following subsections.

5.1.1 Paper I:

This paper explores my initial thoughts related to context and its usefulness regarding its applicability as design and development input in technology-enhanced learning environment. This paper reports the result of applying the initial idea of context perception as a design and development input to be considered while implementing new mobile services to support knowledge workers. The purpose of these efforts was to investigate and identify how contextual attributes extracted from everyday activities could be used for engineering a new mobile service to be delivered to smart phones. Furthermore, this paper explains the way in which different data gathering techniques and a contextual design approach were used in order to identify a particular activity in the librarians’ context that could be supported by a a new mobile service. Generally, the service developed integrated very well into the librarians’ daily work. This fact indicates that contextual instances can be used as design and development input in circumstances where content and services should be designed for supporting tasks in new “nomadic” situations (e.g. learning on the move, listening to a book review or watching a podcast episode about a lecture during a trip).

One of the main challenges explored in this paper was connected to how to find ways to properly grasp the context in which mobile services will be used. Thus, in this paper an initial idea related to context definition was provided. This definition perceives context as a “structure consisted of three dimensions consisting of: location/environment, activity/task and personal interpersonal”. In this manner, this paper identifies the importance of perceiving activity as a vital part of context for the design and implementation of TEL. This initial exploration paved the way for further investigations and developments regarding topics related to users’ context and learning activities in a variety of settings.

5.1.2 Paper II

This paper was also inspired by the results from the Växjö Library trial. As an extension from the the ideas presented in the first paper, this contribution explores more theoretical aspects related to the notions of “value added” services, context and their interrelation. This paper provides a domain exploration regarding context and design and development of computer based information systems. The current challenge in this aspect is the importance of “value of information” as defined by Davis et al., (2006). Moreover, this paper makes an attempt to connect the notion of the value of information with the infological equation suggested by Langefors (1966). This idea is illustrated using a simple mathematical expression in order to represent the value of information. This is an initial approach to actually identify the different factors that may affect the “value of information”. The notion of “value gained” was related to contextuality of information while “value of time needed to process the
information” was related to the users’ skills. This paper in this aspect initiates a discussion around a problem domain related to “contextuality” and “value added services” and formalized the notion of “ontological gap” as the interaction challenge between users and computer based information systems. Thus, the main contribution that this paper brings to this thesis is of theoretical character and is related towards identifying the importance of context for the design and development of “value added” services.

5.2 AMULETS project: Bergunda School trial

This trial took place in the outskirts of the Bergunda School (near Växjö) in the surrounding nature in the spring 2006 as a part of AMULETS project. The aim of this trial was to explore how to design and implement novel technology-enhanced learning approaches that use mobile devices, sensors (in this case GPS) and 2D visual codes (semacodes) to support outdoor-indoor educational activities. These learning activities were designed to make use of new technologies that help to shift interaction behind the “desktop paradigm” as suggested by Kaptelinin and Czerwinski (2007). Another important aspect in this trial was the notion of delivering digital learning content that was contextually related to students’ tasks and location.

Students were divided into seven groups and each group was roughly four children. The activities were conducted over a two-day period with only one group performing at a time. The students in each group were equipped with a smartphone (Nokia 6630) for reading 2D tags and content delivery. They also had a GPS enabled smartphone (HP iPAQ 6515) for navigational purposes and content generation and documentation. The different learning activities were divided into three stages including a pre-activity, a field activity and a post activity (Figure 9). In the pre-activity stage conducted in the classroom, children learned about different aspects of the forest and basic knowledge that could be used to identify the trees in the surrounding nature. 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. At the end of the workshop, children got the first task to solve. A short film with animated characters displayed in the smartphone gave the children a description of their first mission. The children needed to go to the closest forest located 200 meters southeast from the school yard in order to identify a particular kind of tree (among three possible choices) that corresponded to the specific one presented during the pre-activity at the school.

![Figure 9. Bergunda school trial activities](image)

In order to solve this task, the children needed to scan the correct semacode tag attached to the right tree. Each one of the three trees had a different semacode and in case of an incorrect choice of tree, additional information was delivered to the smartphone giving the children new information to solve the task. These exploratory and task based activities continued encouraging the children to learn how to measure the height and age of surrounding trees. During the entire field activity the children
documented their activities by taking photographs and video. The post activities took place in the classroom where all groups presented and discussed the content created during the trial. It is important to mention that this content was tailored to the specific location in which it was generated and it was visualized using digital maps. As a result of this effort, the activities conducted in this trial paved the way for future trials that would move further the interaction and collaboration between groups located indoors and outdoors settings.

One scientific conference paper was published describing these activities. This publication (paper III) was considered as “work in progress” and it described the technological developments and solutions that were used in this trial (such as semacodes, GPS, etc.). From a design perspective, this paper describes the initial ideas related to the activities of the next AMULETS trial that took place at the Växjö Square. From a chronological perspective, this paper can be considered as the initial contribution connected to the design and technical development stages of my research. Thus, a short summary of this effort is provided in the following section. Moreover, a detailed explanation of the learning activities that took place in this trial and the results are presented in the reflective and analytical papers (Papers VI and VII).

5.2.1 Paper III

This paper investigates new possibilities to support teaching and learning that mobile and positioning technologies bring when used in educational settings. Location-based services in educational settings potentially offer advantages of tailoring the content to the specific location/object and thus contextually increasing relevancy (Benford, 2005). This paper presents an initial attempt to formalize the definition of context as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment”. Furthermore, it presents an attempt to conceptualize the context model based on three attributes: location/environment, activity/task and personal interpersonal. From a methodological perspective, this paper presented the use of scenario-based design (Caroll, 2000) techniques for designing learning activities enriched with interaction features using different technologies.

From a technical perspective, this paper explores how computational media using ubiquitous computing, sensors and visual codes can be combined with physical objects. Tailoring content with context (i.e. location attribute in this particular instance) has been done using visual codes (semacodes) and GPS coordinates. The notion of automatic tailoring location to images has been from the metadata perspective where use EXIF (Exchangeable Image File Format) tags to connect specific content (i.e. pictures) with specific locations (using digital maps).

The scenario presented in this paper served to guide the design and implementation of the Växjö Square trial. The main contributions that this paper brings to this thesis can be summarized as follows:

- Context definition and description of the initial idea for a model
- Conceptual design of technology enhanced environments using different context attributes (retrievable by sensors and visual codes)
- Initial exploration regarding the use of contextual attributes as metadata.

5.3 AMULETS project: Växjö Square trial
In this trial, the ideas explored in the Bergunda School experimental case, were further developed. The aim of this trial was to explore the design of novel learning activities using new technologies. One major difference from the trial at Bergunda School is the fact that learning activities in this trial took place both in indoors and outdoors settings, thus bringing additional instances of context attributes as a design and development input. The combination of outdoors and indoors learning activities added an extra level of complexity connected to the design and technical development processes.
The learning activities were divided into three sessions over two days. The students were divided into three groups, each group consisting of ten children. Additionally, each group was divided into two subgroups of five students each, where one subgroup was working indoors in the museum while the other group was outdoors in the city square. The outdoor subgroup was equipped with three smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding the visual semacodes tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. Teacher students supervised the groups during the activities. While the outdoor subgroup was in the field, the indoor subgroup was in the museum. In order to successfully accomplish all the educational tasks the subgroups needed to collaborate using mobile technologies in a variety of ways.

The main activity of this trial was carried out in the form of a collaborative game-like activity that was organized as a set of missions taking place in different locations and across different time periods related to local and regional history. The collaboration between groups was enhanced using mobile IM (Instant Messaging) service, picture exchange and use of visual codes for activity triggering. Furthermore in this trial, the importance of the environment being part of context was identified. Due to bad weather conditions during the first day of this activity, different results were experienced between the groups participating in this trial. A detailed explanation of the different stages of this trial is presented in papers IV, V and VI. Activities performed during this trial are illustrated in Figure 10 below.

From a technical development perspective, this trial was very useful as different collaboration technologies and visual codes were used for implementing and supporting novel learning activities in authentic settings. The activities and outcomes of this trial have been presented in two scientific conference papers. These papers are appended to this thesis while a summary with their main contributions is presented in the following sections.

![Figure 10. Växjö square trial activities](image)

### 5.3.1 Paper IV

The aim of this paper was to describe how a pervasive learning activity taking place across different contexts can be designed and analyzed using AT (Kuutti, 1996). Mobile and pervasive technologies have been used to support the design and development of these learning activities in authentic settings. Thus, the main research question explored in this paper was “how pervasive technologies can be used to support new ways of learning in different educational subject matters”. Moreover, this paper provides insights into how these pervasive technologies can support groups of learners when they, collectively, share their understanding of such a material. From a theoretical perspective, the learning
ideas described in this paper were grounded on collaborative and situated learning theories (Lave and Wenger, 1991). Inspired by Engeström’s activity systems (Engeström, 1987), AT has been applied for the design and analysis of the indoors and outdoors learning activities. From a design perspective, Activity Theory can function as a useful instrument to guide the design process of innovative educational activities. An important contribution that this paper brings is the notion of time as an important aspect related to context. The specific mobile and pervasive technologies used for developing and implementing the learning environment served as collaborative tools to bridge the indoor and outdoors group activities. From a technical perspective, this paper illustrates how different principles of pervasive and ubiquitous computing (Hansmann et al., 2003) can be applied for the design of learning activities to create “augmented physical spaces” (Price and Rogers, 2004). These notions are explored in the paper by showing different ways in which context instantiations can be used to guide the design and implementation of innovative learning activities combined with new collaborative learning possibilities that may arise in these environments. Overall, the main contributions that this paper brings to this thesis are described below:

• Exploration of different contextual instantiations such as: location, environment, task, time
• The use of Activity Theory for structuring and organizing educational activities into a set of simplified instances to be used as design input for learning instances in context
• Exploration regarding principles of pervasive computing and their applicability in the technical development of novel learning activities.

5.3.2 Paper V

The aim of this paper was to document the entire stages related to the design, implementation and evaluation of innovative technology enhanced learning activities. From a learning perspective, this paper explores the notion of “authentic learning” as suggested by Barab et al., (2007). From a technological perspective, this paper identifies the initial concepts and requirements needed for the implementation of the system architecture for bridging indoors and outdoors activities. These issues are explored in connection to the design, development and evaluation of the efforts related to the Växjö square trial. Visual codes have been used to enhance the content of the curricula by bringing multimedia resources and mobile support to a specific location in outdoor settings, thus enriching the field experience. These aspects related to context information have been explored and investigated guided by the ideas behind design-based approach and scenario-based design. This paper also illustrates how ubiquitous computing can be used for bridging indoors and outdoors activities, thus promoting new interaction patterns that go behind traditional “desktop paradigm” and “classroom settings” (Rogers and Price, 2009).

The initial components of the system architecture were identified as being the collaboration and interaction tools, the content repository and the use of visual codes as event triggers. The results of this trial 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 in which they are taking place. Thus, the main contributions of this paper can be summarized as follows:

• Initial exploration regarding system architectures for cross-context collaboration and interaction
• Empirical evaluation of the usefulness of novel learning activity supported by new mobile technologies.

5.4 AMULETS project: Teacher Students trial
Inspired by the results of the Växjö Square trial, we explored further the notions related to new technologies for collaboration and interactions in context of learning activities. This effort was conducted in the field of biology together with teacher students from our university, in order to have another case that validates our ideas and concepts. As a result, a third AMULETS trial has been
designed and implemented. This trial took place on campus at Växjö University in the spring of 2007. Sixteen teacher students from the teacher training program took part of this trial. The students were divided into 4 groups and each one of these groups was divided into 2 subgroups. The aim of this trial was to further explore the notion of collaborative learning activities across contexts and the technological support required in order to achieve this purpose. The field groups were equipped with two smart phones, one for game control and information and one for documentation using images and sound. The control smartphone was used to read the semacodes for the control of the learning activities and for sending messages via a semacode tag. 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 texts in order to determine with the support of a tree taxonomy instrument to which family the tree belongs to, according to leaf buds, bark colour, and other environmental factors. For this third AMULETS trial, the learning activity was refined by running simultaneous trials with four groups and splitting the indoor and outdoor sessions 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. The different images in Figure 11 illustrate how the indoor and outdoors groups needed to collaborate to solve the tasks.

During this activity, students used the digital documentation phone to sent photographs and audio recordings to the base station using a special communication semacode designed for this particular purpose. The groups needed to remotely collaborate using different mobile media content and a web interface in order to identify the tree species.

This trial represents the reflection and analytical stage of the research efforts conducted during this dissertation. The reason for such a categorization is the fact that the design efforts of this third trial have been based on the analysis of the previous two trials. In connection with this stage, two scientific papers (one in journal and one in a book chapter) have been published. These two publications give a description of all design and technological aspects of the three trials combined with the reflective and analytical views based on the cumulative efforts. This is an attempt to provide a cross case analysis of the all the research efforts connected to this project. The journal paper (paper VI) represents a first reflection paper upon the previous two AMULETS trials and it has influenced the design and development of activities in this particular trial. The book chapter (paper VII) includes a description of this particular trial. Both of these papers are actually appended to this thesis, while a short summary of key results is presented in the following sections.
5.4.1 Paper VI

This journal paper presents our design and development approach for bridging outdoors and indoors learning activities with the support of mobile and positioning technologies. The ideas presented in this paper are based on an initial cross-case analysis of the first two trials of AMULETS project. The core material used for this analysis is based upon the empirical data collected from 55 participating students in these two events. A major contribution of this paper is the introduction of a new conceptual framework of context that has evolved from the ideas presented in paper III. Moreover, this paper illustrates the technical architecture of the Learning Activity System (LAS), a key technological component of the context model. LAS makes use of different mobile and pervasive technologies for providing computational support in order to bridge learning activities across contexts. It makes also use of different sensors and actuators as well as different collaboration instances. The results of our experiments, including an extensive empirical analysis of questionnaires and interviews indicated that children enjoyed learning where these collaborative activities were carried out in authentic settings with the support of mobile devices. Summarizing, the main contributions of this paper have been:

- New conceptual framework for context,
- Architecture of LAS as key component for new collaboration and interaction patterns across locations.

5.4.2 Paper VII

In this book chapter the overall efforts related to the design, development and to some extend evaluation of all three AMULETS trials are described. This chapter is enhanced with the empirical data collected during the third AMULETS trial which has been designed using the ideas from the conceptual framework presented in the previous paper (paper VI). This chapter represents an attempt to reflect and analyze the outcomes of all three trials. The main theme of the discussion in this chapter is that the design and development of innovative technology enhanced learning environments activities should be guided by collaborative learning scenarios in context. This claim is supported by the ideas of the proposed conceptual framework and the notion of collaboration in context. This framework provides the designer with opportunities to tackle the challenges of designing for innovative mobile learning activities. The applicability of this framework has been illustrated with three AMULETS trial conducted since June 2006. This framework shows that integrating different aspects of learners’ context into the design and development of innovative learning activities allows for the creation of new modes of interaction and collaborations in context. Our explorations into collaboration in context evolved over the AMULETS 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, students’ subgroups were located indoors and outdoors while the collaboration was mediated by mobile technologies. In the Teacher students trial, the students 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 new technologies.

Overall, this chapter brings in depth reflection and analyzing regarding the notion of collaboration in context. Thus, the main contributions of this publication can be summarized as follows:

- Context framework as a design and development tool throughout all three AMULETS trials.
- The notion of collaboration in context as an “added value” for the design and development of authentic learning activities.
5.5 Summary

The research efforts described in this chapter represent the main empirical base for the findings of this dissertation. From the initial exploration stage at the Växjö Library trial, the notion of context, its definition and conceptualization has been the core of my research endeavours. During the design and technical development stage (the two initial AMULETS trials), the focus was more on the use of new mobile and pervasive technologies in order to implement novel collaborative learning activities in authentic settings. The last stage of my efforts can be characterized by the process of reflection and analysis which is clear indicated in paper VII. In this stage, the notion of context is given a better definition and it is accompanied by a conceptual framework. Furthermore, the use of different technologies enabled the conceptualization of the system architecture and its implementation. The different components of the system have been used to support bridging learning activities across contexts. The table below makes an attempt to summarize the main outcomes based on the research efforts presented in this chapter.

Table 1. Main research outcomes from four experimental case studies

<table>
<thead>
<tr>
<th>Stage</th>
<th>Main outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>• Context as a three pole structure</td>
</tr>
<tr>
<td></td>
<td>• Context and its importance for “value added” services</td>
</tr>
<tr>
<td></td>
<td>• Structuring and organizing learning activities into set of simple features</td>
</tr>
<tr>
<td></td>
<td>that can be regarded as context instantiations</td>
</tr>
<tr>
<td>Design and technical development</td>
<td>• Context definition and initial idea for a conceptual context model</td>
</tr>
<tr>
<td></td>
<td>• Prototype implementation of novel learning activities using mobile and</td>
</tr>
<tr>
<td></td>
<td>pervasive technologies</td>
</tr>
<tr>
<td></td>
<td>• Use of sensors and actuators for acquiring different contextual attributes</td>
</tr>
<tr>
<td></td>
<td>that could be used as metadata for describing content.</td>
</tr>
<tr>
<td></td>
<td>• Initial conceptual ideas of a system architecture</td>
</tr>
<tr>
<td>Reflection and analysis</td>
<td>• New conceptual framework of context</td>
</tr>
<tr>
<td></td>
<td>• Collaboration in context as an “added value” for the design and development</td>
</tr>
<tr>
<td></td>
<td>of authentic learning activities</td>
</tr>
<tr>
<td></td>
<td>• LAS architecture as a key component for new collaboration and interaction</td>
</tr>
<tr>
<td></td>
<td>patterns across locations</td>
</tr>
</tbody>
</table>

These outcomes serve as the basis for the analysis and formalization of the findings that will be presented in the following chapter. Moreover, they also guided further the conceptual and technical developments that are presented in the last publication (paper VIII) appended to this dissertation. Details of the analysis, as well as a summary of paper VIII are described in the following chapter.
6. Cross-case analysis and research results

The aim of this chapter is to provide a detailed analysis of the main outcomes of the four experimental case studies presented in the previous chapter. These results to be discussed in this section have been analyzed from a cross-case perspective in order to present how each one of the experimental case studies has contributed to the main outcomes of this dissertation. Outcomes of the trials and the accompanied publications described in the previous chapter have been conducted over a period of three and a half years. Figure 12 illustrates the ways in which these efforts have been conducted and how the outcomes of the different activities are connected together in order to provide convincing arguments to answer the main research questions explored in this dissertation.

The illustration above describing the organization of this thesis has been inspired by Yin’s (2003) suggestions regarding a multiple case study research strategy. Results of each experimental case study have been accompanied by an individual report in the form of a scientific publication. The initial publications (Papers I and II) are connected to the MUSIS project and they represent the initial explorations in my research endeavours (first research objective, as described in chapter 3). The following three publications (Papers III, IV and V) are related to the AMULETS project and they represent those efforts connected to the design and development of prototype implementations of TEL environments (second research objective, as described in chapter 3). Papers VI and VII summarized in the previous chapter describe a more reflective perspective including a cross-case analysis containing also the results of the third trial from the AMULETS project. In these publications, the focus has been to try to understand the new interaction and collaboration modes that emerge between learners as a result of the use of new tools and technologies (third research objective, as described in chapter 3).

The evolution of this research process provides a clear indication showing how my initial research ideas had progressed; from context exploration to definition and thereafter towards the elaboration of a context model. The last paper (Paper VIII) to be presented at the last section of this chapter makes an
attempt to illustrate the progression of the efforts pursued in this dissertation. In the following sections, the evolution of these research ideas is described from a cross-case perspective.

6.1 From context definition to conceptual model

The research process described in this thesis has gone through three main evolutionary stages, namely exploration, design and technical development and reflection and analysis. Throughout all these stages, the notion of context has evolved and refined. Initially and at the beginning of this thesis, the notion of context was guided by previous work conducted by the author of this thesis, where context was perceived as WWW (Where, What, Who and When) information (Kurti and Ahlepil, 2004).

Based on the research outcomes from the literature review and the empirical data collected during stage two of my work, the definition of context has been modified from previous definitions provided by Brown (1996), Hull et al., (1997), Dey and Abowd (1999), Sharples et al., (2005). Thus, the definition of context provided by this thesis can be stated as follows: “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment at a specific time”. This definition of context relies upon a three-pole structure and time. The three-pole structure consists of the following attributes; location/environment, activity/task and personal/interpersonal and it takes place at a certain time. 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 become valuable inputs for the design and development process of technology enhanced learning activities. The main components of this definition have been reflected in the conceptual context model initially presented in Paper VI. The temporal dimension illustrates the changes in context at different moments (represented as frames in Figure 13). Kaenamponpan and O'Neill (2005) have advocated for the use of time as an important attribute of context. Furthermore, they suggested the importance of the time dimension when it comes to historical dependencies. From this perspective, the proposed conceptual model of context could be regarded as a dynamic entity that relies on a series of static frames. The interrelations and interdependencies between these static frames represent to some extent the context composability in terms of temporal dimension (historical dependencies). The illustration of the suggested context model including the temporal dimension is presented in figure 13.

![Figure 13. Conceptual context model](image)
The surrounding circle of this conceptual model basically defines one frame of context where the activities are taking place at a particular given time. This frame is defined by a time snapshot. Therefore, perceiving context as complex phenomena is represented as a series of interconnected time-differentiated frames. This definition and the proposed conceptual model have been developed inspired by an activity perspective, in which Activity Theory was used to deconstruct it into computational instances.

From a system perspective, a central component of this model is the Learning Activity System (LAS), best described as a computational system and content repository that provides the technological infrastructure for integrating and distributing educational content into the context that a particular learning activity is taking place. Winters and Price (2005) claim also that the context in which an activity is taking place is crucial for learning. The participants interact with the Learning Activity System and with each other, thus promoting different modes of collaboration. In this manner, these research results have been consistent with the initial hypothesis regarding new collaboration and interaction modes and the need for context definition and modeling (grounded on the third and the fourth assumptions, as presented in chapter 2).

In order to address the complexity and fluidity of the learning activities, the context model has been applied in collaborative situated learning environments. The main rationale of doing so derives from the initial two assumptions presented in chapter 2. Table 2 categorizes the different trials mapped according to the components of the contextual framework based on location/environment, task/activity and personal/interpersonal type of interaction and collaboration.

Table 2. Applying the conceptual context model

<table>
<thead>
<tr>
<th>Project</th>
<th>Trial</th>
<th>Location/Environment</th>
<th>Activity/Task</th>
<th>Personal/Interpersonal</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUSIS</td>
<td>Växjö Library trial</td>
<td>The main activity was conducted indoors</td>
<td>Individual task about the content of a particular book</td>
<td>No collaboration, just technology mediated service (multicast)</td>
<td>One-to-many</td>
</tr>
<tr>
<td></td>
<td>Bergunda School trial</td>
<td>The main activity was conducted outdoors with pre and post activities indoors.</td>
<td>Sequentially predefined tasks about nature and history of the local forest</td>
<td>Collaboration between the group members and with other groups in the post activity</td>
<td>One-to-one One-to-many</td>
</tr>
<tr>
<td>AMULETS</td>
<td>Växjö Square trial</td>
<td>The main activity was conducted both indoors and outdoors.</td>
<td>Parallel and simultaneous tasks about the history of the city square.</td>
<td>Collaboration between group members and between the groups</td>
<td>One-to-one Many-to-many</td>
</tr>
<tr>
<td></td>
<td>Teacher students trial</td>
<td>The main activity was conducted both indoors and outdoors.</td>
<td>Parallel and simultaneous tasks about tree morphology and the local ecosystem.</td>
<td>Collaboration between the group members, between individuals with others group and between groups</td>
<td>One-to-one One-to-many Many-to-many</td>
</tr>
</tbody>
</table>

The Växjö Library trial (MUSIS) was conducted in one location (indoors) and it has been guided by the idea of content creation based on users’ activities. In this trial, an instance of activity (division of labour) was used as a generator for the development of a new mobile service. In the AMULETS trial at Bergunda School, the activity was carried out sequentially and took place in both inside-outside-
inside settings; the outdoor part of the activity was designed with predefined stations and tasks. Technological support for the learning activities in this trial enabled tailoring specific digital content to a particular location (using digital maps) and visual codes to trigger the events. In the Växjö Square trial, the activity took place both inside and outside settings (with continuous interactions and communications) and the tasks have been designed in order to promote collaboration. In the Teacher students’ trial, the activity also occurred both inside and outside and it was combined with learners shifting roles in the middle of activity. From this perspective, Activity Theory was used together with design-based and scenario-based approaches in order to dissect a complex social activity into simple instances that could be used as design and development instances (guided by the fifth assumption described in chapter 2). The time dimension illustrated in the conceptual model (in figure 13) was introduced after these four trials have been conducted. Thus, the time dimension did not have any impact in the design and development of these trials. Nevertheless, time dimension becomes an important component of the contextual data model described in section 6.3.

6.2 From context model to system architecture

As mentioned earlier in this chapter, the Learning Activity System is a central component of the proposed context model. LAS can be defined as a system that combines a set of different applications to facilitate and mediate learning activities. These applications are composed by a set of software tools used to support particular tasks within learning activities such as; collaboration and interaction, content storing, visualization and reflections, etc. Different stakeholders of the Learning Activity System include; learners (service users and content creators), teachers (content/service creators), system designers, developers and programmers. Identifying and implementing different requirements for this wide range of stakeholders raised numerous technical challenges that were addressed throughout the different experimental case studies. In the Växjö Library trial, the focus was limited only to the scope and contextual attribute regarding the development of a new mobile service. The implemented mobile service was multicasted to the users using one of the MUSIS channels available from the Collect, Convert and Send (CCS) content repository. For this particular trial, location has not been a crucial factor for the design of the new mobile service and it did not present a functional requirement from a system development viewpoint.

Based on the infrastructure inherited from the Växjö Library trial (a rich digital content repository with flexible metadata management features), new functional requirement were added in order to carry out the second trial. In the Bergunda school trial, the focus was on the design and development of learning activities to be carried out sequentially and outdoors. The physical places for the outdoors activities have been predefined and the learning content to be delivered to the mobile devices was triggered by the use of visual codes. Moreover, the digital content generated by the students during the activities had spatial associated metadata. These rich media content enhanced by location metadata (using GPS devices) were used to recreate the flow of these activities providing spaces of reflection and visualization using digital maps. Thus, this experiment brought new functional requirements in terms of sensors and actuators, as well as presentation techniques to visualize these data.

In the third trial at the Växjö Square, the learning activities were designed having in mind to enhance collaboration and interaction between children with the support of technology. Due to the space limitations of the square, only semacodes were used in order to determine the location of the events, as GPS technology was not accurate enough. This activity was conducted in parallel having both indoors and outdoors groups at different locations. The activities for the outdoor subgroup in the mobile environment were supported by four smart phones used as tools for collaboration, communication and for creating and receiving content. These latest facts were the main reasons for the development of the Activity Control System (ACS), as there was a need to coordinate and synchronize the logic and the flow of the learning activities. Since the activity occurred across locations, there was a need for having different types of collaboration tools. These collaboration tools consisted of an instant messaging service running on a mobile server and a picture uploading mobile application for sharing images in real time.

In the fourth trial, there was access to a more robust technical infrastructure to support learning activities across contexts. In this experimental case, we used for the first time RDF (Resource
Description Framework) techniques to interpret and to store contextual metadata and content extracted during learning activities (Svensson and Pettersson, 2008). These efforts served to define a set of functional requirements to address the importance of metadata for contextual content reusability. In order to address this issue; further conceptual development ideas were conceived relying on dimensional analysis. The results of these efforts led to the introduction of a new component (illustrated by the AE (Awareness Engine) block in dashed lines in figure 14) in the proposed system architecture. The aim of this component is to provide awareness features to the system by enriching user-generated content with contextual metadata. The proposed inference engine relies upon the use of semantic web technologies (such as XML, RDF, RDF Schema, OWL (Web Ontology Language) etc.). Since the main task of this block is to offer interoperability and expressivity of contextual metadata describing learning content to support learners in different situations, this particular block is defined as Awareness Engine. The role of this component is to serve as an inference engine that could be used as a system aware mechanism based on the attributes of users’ context.

The implementation of the Learning Activity System relies upon the use of different software components and mobile technologies, as well as sensors in order to contextually support different learning activities, collaboration and interaction. The central component on the technical architecture illustrated in Figure 14 is the Learning Activity System (LAS). Based on the functional requirements identified by each trial, LAS has been conceived having three main functional blocks, namely the Activity Generator, the Collaboration Tools, and the Presentation Engine.

![Figure 14. The technical architecture of the Learning Activity System](image-url)

The Activity Generator consists of the Activity Control System (ACS), the Collect, Convert, and Send (CCS) repository and the Awareness Engine (AE). The ACS is a software application that controls the flow of the learning activities. The ACS is used to promote collaboration between users and devices.
while retrieving and storing digital content. The CCS 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. AE has been recently conceived and its implementation is under development. Its functionality is to offer relevant support based on the use of inference rules upon contextual metadata to enable content adaptivity and reusability. The collaboration tools provide the literal bridge between groups outside to inside through instant messaging, images, and video etc. The Presentation Engine provides the visualization tools to support reflection in the post activities through the use of metadata and rich media content generated during the group activities. The fourth block of this architecture consists of the Sensors and Actuators that support the Outdoor Activities with location and visual codes (semacodes) to trigger or record events. All these components, as well their interconnections are presented in Figure 14.

In the outdoor activities children have used smartphones and PDAs with GPS capabilities to interact, create and collect content, and to communicate with each other throughout the learning activities. These devices exchange data with the LAS components retrieving and sending content and information, as well as they interact with the sensors. For the indoor activities the children interacted through a web interface linked to the Presentation Engine, thus providing contextual content and connection to activities performed by the outdoors group.

6.3 Dimensional analysis for contextual data model

Guided by dimensional analysis techniques and the context definition provided earlier, the conceptual context model has been enhanced with dimensional data representation as well. This approach enables to simplify context to a defined set of interrelated variables. These interrelated variables are referred as dimensions and in this particular case; they have been defined by the three-pole structure and time. The time dimension becomes important here, especially when it comes to historical dependencies that could affect the user’s profile (i.e. personal/interpersonal attributes), activity and its location/environment. Historical dependencies are referred to changes that happen over time in the relationships between the different variables of the learning environment (given some example of these variables, e.g. users, digital content, location, time, actions, etc) that may influence future context instances of users’ activities. The three-pole structure of the suggested context model (i.e. context frame of our conceptual model) can be represented by the coordinative axis as illustrated in figure 15. Each axis represents each one of the dimensions of the conceptual context model. It should be noticed that this diagram represents just one snapshot (i.e. frame) at a particular given time (t₁). The cloud illustrated in the middle represents the resources available for context acquisitions in a particular situation.

![Figure 15. Dimensional analysis of context](image-url)
Resources in this case refer to different components (teachers and learners, devices, digital content, tools, physical spaces, etc) available in technology enhanced learning environments, as defined by Wasson (1997). Mobile devices used in the different trials are examples of these types of resources. Multiple features of context can be acquired by means of different resources (such as GPS, different environmental sensors, accelerometers, cameras, calendar functions, tagging capabilities etc.), thus enabling their use for the design and development of learning activities across contexts.

If we apply the definition of context suggested in this thesis, the context of a learning activity can be described as the collection of the available resources (in terms of $X_{LE}$, $Y_{PI}$, $Z_{AT}$). If additionally, the temporal dimension is introduced, then the mathematical representation of context definition can be expressed according to the following time dependant function:

$$f(X_{LE}, Y_{PI}, Z_{AT}, t)$$

This expression basically means that context could be expressed as a function depending on location/environment ($X_{LE}$), Personal/Interpersonal ($Y_{PI}$) and Activity/Task ($Z_{AT}$) attributes that change over time. One frame of the conceptual model illustrated in figure 13 represents the particular set of values of each available resources (in terms of $X_{LE}$, $Y_{PI}$, $Z_{AT}$) at a given time ($t_i$). The mathematical representation of this idea can be formalized using the time integration of this function. Thus, if the context function is represented by $f(X_{LE}, Y_{PI}, Z_{AT}, t)$, one instance of a context frame could be defined as:

$$\int_{t_i}^{t_{i+1}} f(X_{LE}, Y_{PI}, Z_{AT}, t) \, dt$$

Where $i$ values can vary between 1 and $n$. Therefore, one frame of this conceptual model is represented as a function that is time independent. This function could be represented as:

$$g(X_{LE}, Y_{PI}, Z_{AT})$$

Each frame of the contextual model could be represented as function of $X_{LE}$, $Y_{PI}$ and $Z_{AT}$ complex variables. Each of these complex variables is a function of other variables as well. These dependencies are illustrated in table 3:

<table>
<thead>
<tr>
<th>Table 3. Possible context dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Context</strong></td>
</tr>
<tr>
<td><strong>Location/Environment</strong></td>
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<td>$u$</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
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<tr>
<td>etc.</td>
</tr>
</tbody>
</table>
(eXtensible Markup Language) has emerged as the dominant standard for data exchange and interoperability between different software applications and systems (Klein, 2001). Thus, different authors have advocated for the use of XML based technologies to tackle the problem of data heterogeneity (Klein et al., 2001; Spyns et al., 2002). The diversity of resources used in TEL environments supports the generation of heterogeneous content data sets. The notion of Heterogeneity in this context means that different resources may provide different context data formats, structures and models. Thus, one emerging problem that arises is that one related to context data integration. Data integration is typically addressed from a syntactic and a semantic perspective (Dong and Linpeng, 2008).

The use of dimensional analysis techniques offers us the possibility of data categorisation according to the three-pole of context. Context data organization and interoperability would offer the possibility for adapting features to content. The context model described earlier potentially enables and supports this notion of adaptivity. Each one of the frames of the contextual model describes in figure 13 represents basically a fully described XML document, consisted of four nodes. Three nodes represent the three pole structure while the fourth node of the XML file represents the snapshot attribute (i.e. date and time). A suggestion for a data structure based on the proposed context model is designed according to a XML schema and it is illustrated in figure 16. This XML Schema provides a method to create precise descriptors that enable unambiguous declaration of data and their attributes. This approach enables syntactic definition of context data structures. The use of XML Schemas enables for context serialization into series of XML documents, where each one represents a frame of the conceptual model. The notion of serialization is well known in programming languages theory and it is based on the fact that an object can be represented as a stream of bits (Szyperski et al., 2002). The use of XML Schemas for XML serialization can be found in the work conducted by Le Goff et al., (2001) and Lowe and Noga (2002).

![Figure 16. Context XML Schema](image)

The XML schema proposed here enables the structural organization of contextual metadata. This structural organization is derived from the three-pole attributes of the context model and time. This contextual metadata schema can be used for describing and enriching different types of content created during learning activities. Moreover, contextual metadata could enhance interoperability of the content generated during learning activities. This interoperability feature would potentially allow for the reuse of content, based on users’ location/environment, or users’ activity/task, or users’ profile and
the interplay between these context attributes. The potential usefulness of these features in TEL environments is illustrated in the following scenario:

During a field study in ecology, a student enters a ubiquitous learning environment consisting of a wireless sensor network. At the start of the activity his/her mobile device starts a software application that will continuously collect data and interact with the sensors in the environment. This interaction means that the software application (i.e. serializer) reads in continuous manner the values coming from the sensors embedded in the environment. Due to the inquiry and exploration nature of this activity, the student needs to take pictures of the different species in the environment for documentation. When the student takes a picture, the application running in the mobile phone generates a snapshot of the sensor values available at the moment the picture was taken. These values are aggregated and serialized as a XML document complying with the predefined context XML Schema constrains. The Awareness Engine (AE) processes the contextual metadata generated in this process together with the picture taken (stored at CCS). Based on these actions, the Activity Control System (ACS) can reuse this picture according to the context in which it was created, thus exercising awareness from the system’s side.

This simple scenario illustrates that the usage and adoption of context data (computable by means of different resources) as metadata may provide some significant benefits leading to “value added” services (assumption number six, as described in chapter 2). These latest research efforts regarding the use of dimensional analysis for context data modelling that can be used in TEL environments were described in the last paper appended to this thesis (Paper VIII). A brief summary of this paper is provided in the following section.

6.4 Paper VIII


This paper present and reflects upon the major research finding of this thesis. It provides a theoretical elaboration regarding the latest developments of context model using dimensional data analysis. These ideas were inspired by the fact that technology is becoming more than ever personalized, and thus a learner-centered approach should be adopted for the design and development of TEL activities. Context awareness and content adaptivity are crucial components in TEL learning environments (Yang, 2006). One important challenge here is how to design and develop technological tools and methods to provide context awareness support. This paper introduces a time dependent context model based on a three-pole structure that can be used to guide the design and support of context awareness applications in innovative TEL environments. Moreover, it introduces aspects of dimensional data modeling that could be used for context metadata organization. Summarizing, this paper’s main contribution is related to dimensional data analysis and contextual metadata organization using XML schemas.

6.5 Summary

This chapter summarizes the outcomes of the experimental case studies. It shows my entire learning path, starting from initial explorations and context definitions up to a more elaborated “computational” context model and dimensional data analysis. The elaboration and implementation of this context model have implications for learning and interaction. By dissecting the different attributes of context, we can gain the possibility to customise and personalize the learning experience for each student or group of students (Christensen et al., 2008). Furthermore, recent mobile and ubiquitous technologies support new interaction modes that enable learning activities to be placed in authentic settings (Barab et al., 2007). In general, the notion of context and the possibility to conceptualize it into a set of simple attributes (features) enables to design learning activities in “augmented physical spaces” (Price and Rogers, 2004). The conceptual context framework proposed in this thesis offers the possibilities for integrating different aspects of the learners’ context into the design and development of innovative learning activities based on new modes of interaction and collaborations in context.
6.6 Limitations

As with every research, it is almost impossible to include all factors and variables that may affect the results of the research activities. The main focus of this thesis has been primarily in the technology/engineering aspects regarding the notion of context applicable in TEL environments. Another noticeable limitation is the fact that only a limited number of context instantiations have been used during all the trials. This limitation has affected the number of functional requirements and this fact is clearly reflected in the conceptual architecture. Technical implementations tested in the experimental case studies have been formally evaluated but only from an attitudinal and usability perspective. Thus, there were no formal measurements related to the effects that these technologies and activities may have on learning. All these facts, combined with a limitation in the amount of users (nearly 100 participants in total) represent another limitation when it comes to the generalization of the research results presented in this thesis.
7. Conclusion and future work

Throughout the different chapters of this dissertation the notion of context in TEL environments has been explored, discussed and elaborated. According to Hwang et al., (2008) “location” and “time” have been identified as being the most used instances for describing the learners’ context in TEL environments. The context model developed and presented in this thesis offers a three-pole perspective on context that brings new insights into learners’ context besides “location/environment” and “time”. The proposed context model includes also additional features such as learners’ “personal/interpersonal” and “activities/tasks” attributes. The outcome of the research efforts presented in this thesis indicates the importance of this different context attributes for the design and implementation of novel learning activities and technologies to support learning in a variety of learning situations. The idea of using the notion of “division of labour” as an attribute for guiding the design and development process in the initial trial proved to increase the usefulness of the mobile service. In this way, the mobile service developed (audio book review) was contextually related to users’ activity. In the second trial, the digital content retrieved on the spot (using 2D visual codes) and also the creation of new rich media content (geotagged photos using GPS) was tailored to a specific location, thus offering ways to contextually connect content to context for the different learning activities in relation to the learners’ location. A similar approach was developed for the third and fourth trials, but here the idea of content in context was also combined with the notion of “division of labour”. The combination of these two approaches served as a tool to promote novel ways of collaboration among learners’ and across contexts. Overall, the context model presented in this thesis offers a wide range of possibilities for using it as a tool for guiding the design and development of novel learning activities in technology enhanced environments.

Learning across contexts is closely related to the use and generation of numerous types of rich digital content. The organization and structure of this rich digital content that may emerge during different learning activities is another important issue to consider while supporting learning in context. Balatsoukas and colleagues (2008) claims that “the lack of concrete specifications can impede interoperable exchange of content” can be identified as on of the main problems in this field. Dimensional data analysis techniques can be used as a possible way for tackling this problem. This approach, combined with the power and flexibility of XML based technologies presents a potential way towards the development of syntactic data interoperability. The context XML Schema derived from the proposed context model could be used as a tool for the structural organization of metadata, thus potentially enabling their expressivity and interoperability as suggested by Monaghan and O’Sullivan (2006). The use of contextual metadata can potentially enhance the reusability of digital content.

A successful deployment of new technology enhanced learning implementations requires for learning activities to be embedded into the learners’ context. Having this in mind, and based on the use of context model and its dimensional data representation in the research efforts conducted, the following conclusions can be drawn:

- The usage of the latest developments in ICT (mainly mobile and pervasive technologies) enables to place learning and exploration in authentic settings (i.e. location/environment contextual attributes) besides the classroom
- The high level of personalization offered by mobile technologies combined with the dimensional view of context presented in this thesis allows for customisation and adaptation of digital content to support different learning experiences. This latest perspective facilitates the adoption of “learner-centric” approaches (i.e. personal/interpersonal contextual attributes) in TEL environments.
- Instantiations of learning activities (mainly throughout the design process) could be used as a catalyst to support interaction, collaboration and active construction of knowledge (i.e. activities/tasks contextual attributes)
7.1 Main contributions

The main contribution that this thesis offers to the research community is a conceptual context model accompanied by a dimensional data model that can be used as a design tool for embedding learning activities in context. Furthermore, the proposed model can be also used as a “computational” instrument to instantiate different features of context in a dimensional and structural way, so that it can help to address conceptual and technical issues related to context awareness support. The features of the proposed context model makes it different from other efforts in this direction as those proposed by Lonsdale and Beale (2004); Brdiczka et al., (2005); Yang (2006) and Hansen and Bouvin (2009). This particular context model has been developed combining the theoretical perspectives presented in the first four chapters and the results from the four experimental case studies carried out during this research. One important aspect in the development of this model is the theoretical view claiming that technology should be used as a mediating artefact for supporting authentic collaborative learning activities. It has been shown throughout this thesis that these contributions can be applied to the field of technology enhanced learning, but not only limited to this field as there are other human activities that could be enhanced with the help of this kind of technological support. The dimensions used to model context are quite generic, thus making them applicable to other application domains. Beside the research community, the notion of context has become increasingly important for the industrial sector too. In recent efforts conducted by Huuskonen (2009) and Nokia (2009), it is mentioned that users’ context is a crucial factor for helping the design and development of new mobile services and user interfaces. Thus, the particular context model developed in this thesis could be used by the research and industrial community as a guiding tool to promote the creation of new ways to personalize services and technologies.

It is important at this stage to recall the main research question presented in chapter three of this thesis:

*How can different context instantiations be used as an input for the design and development of innovative technology enhanced learning environment?*

This thesis provided empirical and analytical support when it comes to the use of context as a design and development input. All four cases described in this thesis provided various insights regarding the use of different context instantiations that have implications for the design and development process of TEL environments. These instantiations shaped the initial view of context from WWWWW information towards a conceptual and representational context model. Different instances of this particular view of context have created functional requirements for the design and development of system architecture (based on LAS). This architecture enabled the implementation and deployment of innovative learning activities and technological solutions by offering services related to learners’ location, activities and profiles. These developments showed the importance of using context as an input to support innovative TEL environments.

*How can context be conceptualized in a set of simple attributes (features) that could be used for guiding the design and development process?*

Context in technology-enhanced learning is a complex socio-technical construct. Human activities (in this case learning) occur in the context in which they take place and they are primarily a social construct, thus their instantiation is rather a complex task. The application of Activity Theory guidelines enables to analyze and decompose these learning activities into set of simple tasks (such as division of labour, set of rules etc.) that could be used primarily as a design input. From a technical perspective, decomposing context is a quite a complex and demanding task. Applying dimensional analysis techniques to improve our understanding of such a construct has proven to be beneficial,
especially since it allows better insight into the complexity of context. The use of computational resources available in the form of different sensors and actuators allows for the technical decomposition of context based on a set of “information that computers know about”. The combination of all these perspectives, as suggested in the dimensional context model presented in this thesis seems to provide beneficial influence for the design and development of TEL environments.

What are the benefits of using computational context attributes (features) as design and development instances for innovative TEL environments?

Lately, members of the research community have been advocating for the use of contextual metadata (Davis et al., 2004; Karypidis and Latis, 2007; Lehikoinen et al., 2007). These authors suggest that the use of this kind of metadata potentially offers a better description of the different digital content resources available. However, these ideas are not supported by a concrete contextual model and a structural way of using and organizing different contextual attributes as metadata. The context model proposed in this thesis advocates that computational context attributes (mainly retrievable by means of different sensors) should be used as metadata that would potentially promote the reuse and interoperability of digital learning objects. Based on recent advances in mobile technologies and the vast amount of available resources (mainly different types of sensors), user generated digital content becomes contextually “enriched”. These trends, combined with the potential that everyone is in possession of these mobile devices pose a number of challenging issues. The perpetual challenge of “information overflow” could be potentially tackled based on the use of contextual metadata. The use of contextual metadata seems to provide a higher level of expressivity than the predefined metadata descriptors (such as author, date, category, language, etc), thus enabling better customisation and personalization of content. Content personalization offers opportunities for personalized learning that according to Järvelä (2006) should take into account contextual conditions. Furthermore, she claims that personalized learning increases learners’ engagement that could lead to better learning results. From this perspective, the use of computational context attributes for describing digital content offers benefits in terms of personalized learning and potential improvements of learning outcomes.

The context XML schema presented in the former chapter could be used as an organizational constrain for structuring this new type of contextual metadata. Thus, the emergent learning objects created during a particular learning activity could be organized and reused in accordance to users’ locations, activities and profiles. Moreover, this approach could be useful for supporting different type of learning and interactions, as it helps for the personalization of learning content and experiences.

7.2 Future work

A Ph.D. thesis represents a stepping-stone for a researcher that should lead towards new intellectual challenges and endeavours. From this particular perspective, this thesis fits this pattern. My future research activities will still be connected to the field of technology-enhanced learning but they will be more inclined towards development challenges emerging from the proposed context data model. These efforts will be oriented towards the categorization and reusability of new content (i.e. digital learning objects) created during learning activities and by learners themselves. These objects have been referred recently as “emerging learning objects” (Hoppe, 2009). The main challenge here is related to the fact that these media objects are usually created and generated in an unanticipated way, thus making the predefined metadata structures inapplicable. Thus, relying upon the notion of contextual metadata for describing these media objects seems to be a rational way to address those aspects related to content reusability and categorization.

One of the advantages of the dimensional context data model is the possibility of serialization using XML Schemas. Currently, I am in the initial development stages for the creation of a conceptual scheme to address the issue of contextual metadata and their applicability to emerging learning objects. This conceptual scheme is built upon the layered integration model proposed by Dong and Linpeng (2008). Concerns related to interoperability and expressivity of metadata identified here, are addressed with the help of RDF (Resource Description Framework) and RDF Schema (Monaghan & O'Sullivan, 2006). The rightmost part of figure 17 below depicts the ability to add meaning to and perform inferences based on the RDF resources through OWL (Web Ontology Language) and RDF.
Schema. In parallel to the syntax-concept-semantic definition, is the corresponding technology infrastructure starting from mobile sensor networks (context acquisition) to mobile mashups (binding content and context) and content repositories (storage) to support this process. This approach related to the use of the context model for data integration, will bring new functional requirements regarding the system architecture. Another issue that will be focus of my future efforts is related to Context Oriented Architectures (Elsafty et al., 2008).

![Figure 17. Conceptual scheme for achieving interoperability and reusability of emerging learning objects](image)

Some of the challenges that have been addressed in the former paragraph will be explored as a part of the upcoming efforts connected to two new research projects I will be involved in. In the LET'S GO (Learning Ecology with Technologies from Science for Global Outcomes) project I will investigate together with my colleagues at CeLeKT how the ideas of seamless learning and “open inquiry” can be supported by features of context awareness and content adaptivity. In the OpenScienceResources EU project, the focus will be on exploring innovative solutions for metadata (based on context features) handling of digital science education objects. Moreover, in this project I will investigate those issues related to quality of services in TEL, as suggested by Gafni (2009). I expect that the outcome of these efforts will bring new functional requirements and possibilities for improving the quality of services. It is expected that these results will be used for refining the current LAS architecture. Hopefully, these improvements may lead to the evolution of LAS towards a Context Oriented Architecture that would facilitate data integration and context awareness support inspired by the context model and related ideas presented in this thesis.
References


Collection of papers


Contextual Design of Mobile Services to Support Knowledge Workers in Library Settings

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Abstract

In this paper we report the results of our work exploring the design and implementation of mobile services to support knowledge workers. The purpose of these efforts was to investigate and identify how contextual information extracted from everyday activities can be used to generate the content of a mobile service to be delivered to smart phones. In this particular effort, 10 librarians from Växjö public library participated in this trial during a period of 30 days. Generally, the service we developed integrated very well into the librarians’ daily work.

Keywords: contextual design, mobile learning applications, context awareness.

1. Introduction

Pervasive computing is gradually having an important impact on the ways people communicate and interact and it also serves as a basis for the development of sustainable and usable mobile services. One of the main challenges we are facing as educational technology designers is how to properly grasp the context in which mobile services will be used. The main reason for using context as the starting point for the development of a new service is based on the idea that attractive and useful services should have a high level of embeddedness and mobility [1]. These two concepts are strongly connected to the ideas and visions of ubiquitous computing environments. Mobile phones’ usage is just a particular example of this perspective [2].

Based on previous results of our own research regarding the design and use of mobile services and smart phones with university students [3, 4], we identified that the degree of usability of a service is closely related to its content and the situation in which the service has been used. The results of the surveys we conducted with students from two courses at Växjö University that participated in our trials during a period of 3 months indicated a decrease of usefulness of the service if the instructor didn’t adapt the content of the service to the new context (learning on the move supported by the use of the mobile phone). Guided by these findings, we decided to explore the idea of how to use context as the base for content generation for the new mobile service. Thus, we designed another trial aiming at testing these ideas together with librarians to partially support knowledge activities in the context of a library setting.

2. About the MUSIS project

In order to explore the ideas described in the former section, we took advantage of the platform we developed for the MUSIS project, as it served very well for our research purposes. The MUSIS project was designed to explore, identify and develop a number of innovative mobile services with rich multimedia content to be distributed over wireless networks in university campuses [3]. The content included general such as music video and radio clips and news feeds, and also campus-specific information such as reminders and announcements of changes in the class schedule, summaries of lectures (in audio and video format), and preparatory notes for upcoming sessions.

3. Problem domain

Our problem domain comprises aspects related to contextual information, content and mobile services. Based on previous research in the field of contextual information, there are a number of definitions dealing with what context is. Chen and colleagues [5] define context as the “Understanding of a location, its environmental attributes (e.g. noise level, light intensity, temperature and motion) and the people, devices, object and software agents it contain”. Another explanation is given by Raento and colleagues [6] in which context can be defined based on location and personal attributes. Our definition of context slightly differs from these definitions because we conceive context as a three layer structure having 3 different dimensions defined as...
follows: location/environment, activity/task and personal/interpersonal.

In the rest of the paper we will describe our efforts that focus on both, activity/task context (defining the content of the service) and technical context (delivering the service) to support the activity of knowledge workers. The coming section introduces the activities we conducted regarding the design and use of mobile services in a library setting.

4. Method and procedure

Ten librarians at Växjö Public library (http://www.växjö.se/bibliotek/) were equipped with Nokia 6630 smart phones with 128MB and with GPRS access (free of charge) to the MUSIS channels (including text, audio and video material) for a four weeks trial during the period October-November 2005.

We used different data gathering techniques in order to identify and define the context in which the new service will be developed. The data gathering techniques consisted of questionnaires, interviews and observations. All data we collected provided us with a solid base to define the user’s context. The contextual information we gathered was used to define the content of the new service.

4.1. Subjects

The group contained five females and five males, ranging from 40 to 50 years old. One subject left the trial due to illness during the first week. Only two subjects didn’t previously have a mobile phone. All of them had basic IT proficiency. The test group represented 14% of the total workers. With this focus group we conducted two surveys at the start and end of the trial, individual structured interviews, and two workshops. The interviews were conducted during the second week of the trial. Workshops were held at the beginning and at the end of four weeks trial. All these activities, combined with our observations, provided a good empirical foundation for the service design and implementation phase. Besides information about the user’s profile, we collected data about users’ mobility perception and use and some basic information about their activities and tasks.

4.2. Interviews

We conducted nine interviews with all participants during the second week of the trial. For these interviews, we developed a well-structured questionnaire in order to get more specific information about their personal experiences in this trial. In general they regarded the Smartphone and the MUSIS services as interesting tools that have the potential to assist them in their work and communication with their readers. Based on the questionnaire, we found that most of the librarians (seven of them) spend most of their working time giving their readers specific information about the content of the different books.

Together with the librarians, we came with the idea of creating a repository of audio clips containing material related to book reviews (content of the service) that can be delivered to mobile phones via cellular networks using GPRS (technical context). All librarians we interviewed were very positive to this idea, mainly because in this way they can find new ways to be in contact with their readers independent of time and space constrains (it should be noticed that a vast majority of the Swedish population has mobile phones that can play digital audio).

5. Implementation

The core technology used in the MUSIS project is the MUSIS server, consisting of a multimedia repository and a content management system defined as CCS (Collect, Convert and Send). This latest software component has been developed by us at Växjö University [3, 4]. During the trial, one of the librarians created a number of audio clips in order to test and evaluated this content. The audio clips were then uploaded to the MUSIS server and then delivered to the mobile phones.

Figure 1. A Conceptual schema of the contextual service
The top layer of the schema illustrated in figure 1 represents the MUSIS server. The object with the number 1 in this diagram represents the CCS module. The database with the audio clips containing the book reviews is marked with 2 while number 3 represents the content and technical context of the new service. As the audio clips contain metadata associated information, the same content could be delivered to different users and profiles. It should be noticed that the CCS system allows generating different instances of the same content (like podcasting or MMS).

Figure 2 – MUSIS interface

Figure 2 illustrates the NOKIA 6630 with the interface of the MUSIS client to access the different mobile services we have developed. As shown in the illustration below users could access the content related to cultural news (Kulturnyheter), audio book reviews (Caroline tipsar) and information about new books (Tre nya bocker).

6. Evaluation

In order to assess the quality of the services and the impact of this trial we conducted a final survey during the last day of our project. Our main issue focused on the usefulness of the audio clips containing the book reviews, and whether this service should be offered to the readers on a regular basis (a couple of times a week). Seven subjects thought that the audio clips with the book reviews would be very interesting and useful but they needed more time in order to explore these ideas. One participant was so positive that wished that such a service could be introduced within a year, while another questioned the librarians’ ability to find time and resources to produce such digital content. None of the trial subjects thought that the audio book reviews service would not be useful, although that option was listed on our questionnaires. These initial findings support to some extend our early claim that for higher usability of the mobile service, contextual information should be used as the basis for generating the new content.

7. Conclusions and further developments

Using different data gathering techniques and a contextual design approach, we were able to identify one particular activity in the context of knowledge workers in a library setting that could be supported by a mobile service. The content associated to this activity/task basically represented for us the content of the new service. The proper channel for delivering the service was defined as technical context. The new service has been well accepted by the users providing some indications that right content in the right situation is an important factor for mobile services adoption and acceptance. This fact indicates that contextual design techniques can be useful in circumstances where content and services should be designed for supporting tasks in new “nomadic” situations (e.g. learning on the move, listening to a book review or watching a podcast episode about a lecture during a trip).

We will continue our research activities within the field of contextual information, mobility and learning as part of the efforts we will conduct in two new research projects where we will explore other dimensions related to contextual information such as location (using GPS) as well as personal/interpersonal attributes.

References

Increasing the value of information: Putting content in context: is that enough?

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Abstract. This paper presents our views concerning the use of context as a part of the participatory approach in order to provide content in context to increase the value of information. Our aim is to decrease the “ontological gap” that exists between users and information systems. Our focus is to close this gap by using contextual information. We introduce a three layer perspective view to context that takes into consideration location / environment, activity / task, as well as personal / interpersonal attributes and instances. Using this structure, we present how we shaped and designed content that is contextually related to the users, in two of our cases. In the first case (Växjö Library) we make use of the activity/task layer of the context information while in the second case (BoardFamily and FreerideHub) we make use of location/environment and personal/interpersonal layers. In both cases, we experienced increased usability thus higher value of information.

Introduction

Over the last four decades the purpose and perspectives regarding the design and implementation of information systems has remained the same, to support and facilitate human intellectual activity. This was the main aim of the first designers of computer based information systems (Langefors, 1966). These computer based systems are mainly used for production, processing and transmission of information. Initially the cost for producing the information was rather high and as time passed this cost has been radically reduced, due to the rapid development
of hardware and software. One of the main current challenges according to Davis and colleagues (2006) is how to increase the value of information. In this paper we will explore the possibilities for increasing the value of information using contextuality.

The aspects of value of information were addressed by Langefors (1966) with his infological equation. The purpose of his equation is to synthesize human centered and computer centered perspectives in information systems’ design. Based on this equation and using a simple mathematical representation, we can formulate this equation (see bellow). This representation is based on the concept that the value of the information can be expressed in economical terms, as it can be described as the difference between the value gained from information, the value spent for producing and transmitting the information and the value of time spent in the interpretation of the received information.

\[ V_i = V_g - V_{pt} - V_t \]

Where \( V_i \) represents the value of information, \( V_g \) represents the value gained from use of information, \( V_{pt} \) represents the value spent for producing and transmitting the information and \( V_t \) is represents the value of the time needed for the interpretation of the information. As already mentioned, the value of \( V_{pt} \) is continuously decreasing and it should tend to minimum (close to zero) in the coming years. In order to increase the value of information (\( V_i \)) we need either to increase the value gained from information (\( V_g \)) either to or decrease the value of the time needed to interpret \( V_t \). We will explore and describe in this paper our current efforts while trying to increase the value of information for supporting everyday activities. Thus, we will illustrate and analyze the results of our projects MUSIS, BoardFamily and FreerideHub. The main objectives of the MUSIS project (www.musis.se) are to design and deliver innovative multicast mobile service to the smartphones (Milrad et al., 2005, 2006). The BoardFamily (www.methodmag.com) and FreerideHub (www.freeridehub.se) project objectives have been to visualize the flow information between groups of people in online communities. These projects specifically looked at the social relationships between locations and people.

The paper is structured as follows; in the following section we will describe the problem domain that guides the research efforts presented in this paper. In the next section, we will present how different participatory design instances have been used in the development of a couple of examples presented in later sections. These examples are defined as contextual information services. We will continue with a section that describes two empirical examples that used the participatory design in two different design activities. This section will be followed by some
analysis and reflections based on our results. In the last section we will present our conclusions and the directions of our future research.

Problem definition

Based on the ideas discussed in former section the value gained from information can be increased if some aspects of the context in which information is used are taken into account in the design process. In this paper we describe the contextual design aspects integrated with participatory approach. Our claim is that contextuality should be considered a key aspect of participatory design.

There have been numerous attempts trying to define what context is. Hull and colleagues (1997) defined context as “aspects of current situation”. Another definition is given by Brown (1996) where he defines context as “elements of the user’s environment which the computer knows about”. One other more precise definition of context is given by Dey and Abowd (2000) where they define context as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”. Our view of context slightly differs for those definitions. We define context as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment”. Thus, our definition of context relies upon a three layer 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.

Bridging the ontological gap

In general we think that basically there is one path with two directions to decrease the “ontological gap”¹ (see figure 1) and increase the value of information. The first direction is to contextually relate the information (i.e. content) to the user while the second one is to educate/train the users to make better use of information. Both directions tend to close the “ontological gap” that exists between the user and the information system. The first way basically tends to close this gap by moving information systems closer to the user (context awareness) while the second way tends to close this gap by moving the user closer to the information system (user education/training). In this paper our focus will be

¹ The term is borrowed from philosophy where according to Michael Silberstein it defines is the gap between fundamental ingredients/parts of reality that are not conscious (such as particles and fields) and beings/wholes (such as ourselves) that are conscious (Freeman, 2001)
just in the direction of using contextual information instances in order to close this ontological gap.

Over the past years, context awareness has become a research approach for closing this “ontological gap”. This research is mainly focused on the technology aspects mainly due to the rapid development of technologies and their use in pervasive and ubiquitous computing environment (Lyytinen & Yoo, 2002). These environments tend to bring the information system closer to the user. This was also the aim of pervasive computing as it has been defined by Weiser (1993); “Enhance computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user”. Within the field of computer science, contextual computing is the discipline that explores the design and implementation of systems to provide new features for information systems. The main idea is to provide content that is aware of the user’s location and/or aware of the user’s activity/task and/or aware who the user is; resulting in more benefits for the users.

Multiple contextual computing systems have been developed by making use of one of the attributes of the three layer structure previously described (Benford, 2005). The most prominent representative of such systems are location based services that make use of the location/environment attributes of context. Other examples are recommender systems that are today available on the web (like Amazon.com, Google etc.) exploring users’ activity/task attributes. All these systems are based on the idea to provide content that is contextually related to the user, enhancing the value of information (Flensburg, 2002, 2003; Flensburg & Milrad, 2003; Gappmaier, 1997; Greenbaum, 1979; Greenbaum & Kyng, 1990)

The ideas presented in the previous sections provide a brief overview describing how contextual information can be used to augment the value of information by increasing its relevancy toward the users. The problems we are addressing in this paper are what methods and ways should be used to include those aspects related to contextual information as input to the design process.
Different perspectives of using the participatory approach in contextual information system design have been introduced by Scandinavian authors since the 70s (Ehn, 1979, 1988; Greenbaum & Kyng, 1991; Greenbaum, 1979; Greenbaum et al., 1990). Their claim is that involving the users in the design process will lead to a higher acceptance and usability of the system. This involvement resulted in the users regarding the new information system as their own product. These new systems support the way users want to work and reduce their frustration with high level of automation (Beyer & Holtzblatt, 1998).

Since then, different patterns of user involvement have been introduced. Those patterns were mainly developed for more “passive” user involvement. Examples of these patterns are scenario based design (Carroll, 2000), prototyping (Floyd, 1989) and recommender system methods (Shardanand & Maes, 1995). Scenario based design represents an approach for contextual information system design. The user’s participation in this method is simulated while the recommender system approach utilizes the user’s participation to improve the system output based on the users’ context. We describe these instances and show the similarities with methods used in our two case studies. The scenarios are used to define the requirements of the system while in our cases we use a method with more active user participation. The recommender system methods automated ways to shape the content that is contextually related to the users. In our cases we actively involve users to help shape the content.

Inspired by the ideas presented in the former sections, we designed and implemented a couple of experiments in order to validate our claims with regard to how to design services that provide users with relevant contextual information. In the next section we describe the results related to the design and implementation of contextual mobile and web services.

Case studies

Below we present two case studies that explore how we applied our layered model of contextual information together with participatory design techniques to increase the value of information. The first case describes our activities at Växjö Public Library where the goal was to develop contextual mobile service to support users’ daily activities. The second case describes two web communities used to explore how large groups of people share and value artifacts in the context of location and activity.
Växjö Library case

The purpose of this trial was to investigate and identify how contextual information extracted from everyday activities can be used to generate the content of a mobile service to be delivered to smart phones. The trial took place in Växjö Municipality Library (http://www.vaxjo.se/bibliotek/). The Library has 70 workers that serve the community of 75000 inhabitants. It is a network organization and has several branches in order to have better communication with community. Our target was specific user group (i.e. knowledge workers) and specific context attribute (activity/task).

Since the users’ context consists of three different attributes (location/environment, activity/task and personal/interpersonal) is not a constant but very changeable variable defining it was the hardest part. Different data gathering tools were used in order to grasp the user context (Jones & Marsden 2006). We used triangulation view on the users’ daily activities. Initially we started with a questionnaire that allowed us to get some raw data concerning the users and their context. Those data served as input for questions in interviews that were conducted later on. The last tool used for data collection was observation. All these three methods provided with good empirical background concerning user context. The second phase was basically a constructive research with a building process in it (Järvinen, 2004). The methodology used in this project is illustrated in the figure 2.

Since we define the context information as a three layer structure, we illustrated it as a 3D structure. Each of the data collection methods defines one dimension of such structure. Based on our observations, we were able to identify the daily user’s activities while with questionnaires we were able to define the domain of

![Figure 2. Methodology](image-url)
their activities. The interviews served us as tool to get in depth information about the user activities in the specific domain and discuss with them potential content of new contextual service. All data gathering tools enable us to have solid foundations to define the user context. This contextual information was used as an input in the building process, since it helped us to define the requirements and the content of the new service.

Settings of the experiment

In this particular effort, 10 librarians from Växjö public library participated in this trial during a period of 30 days. These 10 persons serve as the focus group for our experiment. User involvement was achieved through workshops and data gathering activities as suggested by Jones and Mardsen (2006). From a quantitative perspective this group presented 14% of the workers of the library. The composition of the group was such that it represented a respectful sample to validate our results.

All of them were equipped with Smartphone Nokia 6630 and they had GPRS access (free of charge) to multiple different audio and video materials that where provided through MUSIS servers.

Due to illness one participant after initial stage (first workshop and initial survey) left the group. Therefore the end result of this project has been inducted only from the feedback that we got from nine users.

The context in this trail was related to users’ tasks and activities and didn’t reflect any location/environment attributes. We limit this definition of the context only to the activity/task of the user in this case since in the location/environment attributes (such as location, temperature, noise level etc.) were constant. The first questionnaire took place on the first day of our trail, the questions were divided into three groups. The groups of questions were concerning user profile, users’ mobility perception and user context (i.e. identifying user tasks and activities).

User profile

In this section we present the profiles of the users that participated in this trial. These profiles were derived from the answers we got from the users in the first survey we conducted in the beginning of the trial. In general users in this experiment have had basic IT proficiency and experience with mobile communications. Only two of them didn’t previously have a mobile phone.
User mobility perception

This group of questions was related more toward identifying how do users perceive mobility and what is their frequency of use. Most of users as main motive when choosing mobile phone selected functionality (8 of them) and as second was price (5 of them) while ergonomic design (4 of them) and brand name (3 of them) were their third and fourth choice respectively. The interesting fact is that they basically in very rare occasions use advance functions rather than making or receiving call or sending SMS (in average two per week). Information gathered served us with valuable insight concerning use of mobile devices form knowledge workers.

User task (Contextual information)

Our focus was to identify the main activity during their work hours working with their clients (readers) that they spent most of the time. Seven of them answered that most of the time they spent in providing the readers with information concerning book content. This means that when they deal with library readers, most of the time they spent in providing them (readers) with information about the book content. The other three users deal with other assignments. For most of the subject (six of them) in this trial the best way to communicate with library readers was personal (live at site) communication. Most of the users (eight of them) thought that mobile technology can enhance their way of performing ordinary tasks, while two of them have had doubts.

Interviews

We made nine interviews with subjects during the second week of the trail. The interviews were structured and were conducted with all users. We used this approach because we wanted to draw the map of the domain under study (Järvinen, 2004). In our interviews we didn’t just wanted to get from the users information about new service but we also in our interviews we presented the opportunities of the new service. This is also consistent with Järvinen (2004) recommendations concerning the use of interviews in the building process.

From those interviews we understand that for most of the users it was convenient and fun to use advanced functions that Smartphone offers. For some of the users (four of them) adjustment needed in order to use the advanced functions of the Smartphone (user friendliness problem). For all the users the services provided through MUSIS were interesting and relevant and they find them pleasant to use. They didn’t change very much the perception concerning use of mobile phone, but for the experimental purposes they started using the advanced functions more
often. In general they regarded the Smartphone as necessary tool in their everyday life that can facilitate their work and communication with their readers.

Since based on the questionnaire, we found that most of the user (seven of them) most of the time while dealing with the readers spent in providing information about the content of the book. This information served us as input for experimental implementation of new mobile service. The idea was to create a repository of audio reviews of the books that can be accessible via mobile phone. All of the users interviewed were very positive concerning this idea of implementing such service.

Evaluation

After we designed the new mobile service (i.e. audio book reviews), users had the opportunity to test it for two weeks. After those two weeks we organized a workshop with all the users participating and conducted the last evaluation survey.

Most of the subjects (five of them) found MUSIS services were very interesting and relevant to their activities. Three of the subjects answered that MUSIS services were interesting but not useful for them while one subject answered that services were irrelevant since the content didn’t fit the expectations.

The most important question for us was the question dealing with the usefulness of audio book reviews. The users needed to answer what they think about the usefulness of audio book reviews if this service would be offered in regular basis (couple of times per week) to the library readers. Seven subjects answered that yes it would be useful but they would need more time to explore the service. One subject answered that yes, it is completely useful and this service should be introduced already next year. One subject answered that maybe the service might be useful, but it will be difficult to find time and resources to produce the content. The important thing to mention is that none of the subjects answered that the service can’t be useful at all for them even that they had that answer as a possible choice.

Overall from the last workshop and the survey we conducted with library workers we got some empirical backup concerning our initial idea that for developing a contextual service, participatory approach must be used. Despite the short time, the new service was well accepted by the participants of the trail mostly since it was directly related to their task and since they regarded the new service as their own product as well. All this was achieved by defining the requirements of the new systems using and shaping the content of the new service using active participation.
BoardFamily and FreerideHub - Community Platforms

These two projects were conducted at the Interactive Institute\(^2\) and explored how to create knowledge based community tools and methods for understanding how information spreads between groups of people. We focused on the design and implementation of cross media systems that enabled a community driven approach along the context layers of location / environment and the personal / interpersonal.

The purpose of the trial was to utilize large communities of people with like interests to try to understand how special information (trends) spread through social networks. Our focus was on specific user groups of professionals in the action sport field (media producers, event organizers, athletes, and dedicated enthusiasts). We were interested in the specific context attributes of location and personal/interpersonal. Based on previous test projects we choose to use a human centered approach (Preece et al. 2002). Our gathering tools used to grasp the user context also used in our layered method to gather the users’ activities out around the mountain and in front of their computers (Jones and Marsden 2006). Initially we started with workshops with recruited focus groups and this data served as design foundation and served as a foundation for iterative process for the next workshops and interviews later on. The last tool we used was observation during events where the communities where publicly released as ongoing commercial projects.

The observations helped us initially identify the users’ daily activities when it comes to sharing information and what information they would be likely to share versus more private information. This was quite location context based, since the activities generally require special landscape features the target group was likely to share exact location attributes. The workshops and interviews gave us in-depth view of how they used the system and what problems and ideas they had about features. These gathering tools provided us with a foundation to define the user context and develop the community platform services.

Settings of the Trials

The Boardfamily community started in August 2004 and the project ran until July 2005. The project was divided up into four parts, concept, development, testing and refinement, and release with hand off. Concept and development where limited to a reference group of 10 people who we worked with as involved parties or the stakeholders. As the project moved to the last 2 phases the stakeholders

\(^2\) Spikol was affiliated with Interactive Institute from 2003 – 2006 before joining CeLeKT-MSI at VXU in 2006.
where expanded to include community members resulted in about 80 active users about 25% of the total community before the release and hand off.

For FreerideHub the same process was followed but in a condensed manner of 5 months. The project started in April 2005. We started with a core group of 12 people including researchers. For the initial workshop the group decided on the services for the community. The community platform software was further developed to meet the group specifications. Follow up meetings help with the core group with new members. The community was released at an event in July 2005 and through interviews and on-line forum the development continued with a larger group of involved parties.

The community platforms have some key features in the members’ section that enable the visualization of their network, the social browser. This tool allows the member to be in the center of his/her egocentric network and by clicking on their friend’s icon can begin to browse friends of friend to find like-minded people that they can invite to join their network. From the personal section the users can upload their photos and contextualize them with built-in key words, location (resort) and their own tags.

Utility of Artifacts and Action Research

Using Järvinen’s (2004) taxonomy for research methods the work clearly fits into the research stressing utility of artifacts. The projects consisted of artifact building and evaluating approaches in Järvinen’s framework it should be seen as action research, where building and evaluating in the same process. In the two projects we worked with a test bed concept where the researchers and developers where also key participants in the target group.

Users / Developer / researcher / profile

The BoardFamily and FreerideHub community projects where approached in the participatory design research context (Muller, 2001). Since the researchers are active part of these two communities our approach was integrated in identifying the problems and working with users. Our profile for the project has been dedicated enthusiasts for snowboarding and mountain biking. For Boardfamily the users are centered on the readers of Method Snowboard/DVD Mag a pan European publication that collaborated in the project. For FreerideHub we approached the community from the local scene and developed the project with them to drive regional development with Åre Mountain Bike club.

For the Boardfamily the core team was made up 10 people with 8 being male and 2 female between the ages of 20-40. All participants had digital cameras, Internet
access at home and work. For FreerideHub we actively recruited more female participants and the core group was 10 people with 4 being female and the ages were from 20-40. For the second round workshops the group was expanded to loose group but the ages and male female breakdown remained the same.

User context

The projects have been designed to work with the user context and support their interests and connect them to other people that share the same. Location and environment play an important role in the practice of these personal/interpersonal connections. The photo galleries and user profiles have location tags that enable automatic placement of photos in the location section of the site and where the user is at the moment. The personal and interpersonal was realized in the social browser where users created profiles and visualized their network of friends. The screen shot of the social browser is illustrated in the figure 3, bellow.

![Figure 3. - A screen shot from the social browser](image)

User involvement activities

The projects concept and development process was iterative and started out with a series of workshops between the projects researchers and collaborators. BoardFamily was the first community developed. From these initial concepts paper and screen sketches where developed and refined in larger workshops with community members who where recruited from the local areas. From this point we developed the website and then recruited people from the old community to test the new site with simple questionnaires, face-to-face meetings, and online forum. FreerideHub was developed in the same process but with the exception that the initial workshops started with the BoardFamily site. Both community platform projects focused on using contextuality and participation across the location/environment, activity/task, and
personal/interpersonal. Since the communities are centered on location and activities and the personal context of the data was the primary focus.

Evaluation

The biggest issue was the lack of interest in users tagging photographs, sharing albums, and utilizing the location keywords. From follow up interviews and statistics we see people uploading in BoardFamily on an average of 1 image per user. When we developed FreerideHub we simplified the photo gallery (increased user friendliness) and the average is 3 images per user.

The social browser has raised issues, as well in terms of it is intended use of the connecting new people versus people just connecting up already know contacts. Similar issues of creating isolated functionality that is limited to the community platform opposed to a more open standard with syndication, examples being the photo-sharing website Flickr.com combined with Google’s Blogger web diaries.

These points raise the question about to better utilize context services in the process of design in large-scale communities. Where even with medium size participatory practices users utilized the context features differently then designed. The next step is to run a serious of workshops and interviews to understand why and to consider a more open approach enabling users to utilize syndication feeds between different services

Analysis

In this paper we have presented two different cases that involved users in the elicitation and design of a couple of the services to support their daily activities. Both of those cases are presented to look at the usability of the service and artifacts produced. The focus was to apply our layered model of contextual information together with participatory design techniques to increase the value of information. We focused in the use of instances of contextual information with the aim to close the “ontological gap” between the users and the information systems. So far the field of context awareness has been tackled from the computer centered perspective. In our cases we used contextuality with a participatory approach for increasing the relevance of the content provided.

User participation can be used in different ways, from data mining tools to direct user involvement. Initially we argued that one way for increasing the value of information is to contextually relate it to the user. In both of our cases we describe the activities for design of the information systems and for the content shaping.
In our two trials we applied our layered model of contextuality integrated with active user participation and we received better usability of the artifacts produced. In the first trial, we showed that increase of the value of information can be achieved by relating the content to the users’ activity/task. In this case it is similar with scenario based design where scenarios are used to define the requirements. Also the content was contextually related to the user activity/task similar to recommender system.

In the second case the increase in value of information was based on the use of location/environment and personal/interpersonal attributes of the context information. The biggest issue that appeared during this trial was lack of interest from users to tag the pictures taken. This aspect was mention by Wickens (1992) when he mentioned that manual metadata generation should be avoided because the users might conceive such process as annoying task.

The interesting part is that both cases used instances of contextual information for increasing the value of information. In the first case it was related to the activity and task while in the second case is more related to the location and personal/interpersonal attributes. In both cases the user’s participation was based in the data gathering techniques, as it was suggested by Jonas and Marsden (2006). This was very important because in this way we were able to understand the user needs by incorporating them and the contextuality in to the process. For grasping the user context, the participatory approach or at least an instance of it should be used. All this will help us to come closer to design of information system that will enable us to deliver proper information in proper format through proper device in proper location at proper time to proper person.

Conclusions

So far contextual information systems have been designed and shaped using different methodologies like scenario based design, recommender system methods etc. All these methodologies are used aiming at understanding the users and their activities and entail some degree of user’s involvement. The participatory approaches have been developed by Scandinavian authors since the 70s in the time that we didn’t have such advance technologies as we have today.

We applied our layered model of contextuality together with the participatory approach in both of our cases with the aim to increase the value of information. This was done by using instances of contextual information as a design input. These instances improved the content of the system by making it closer to the user location/environment and/or activity/task. In the library case we made use of the activity/task contextual instance while in BoardFamily and FreerideHub
location/environment and personal/interpersonal instances were used. In both cases we experienced higher usability despite using different instances of contextual information. The usability was raised because of the increase value of the information that the users received. Table I presents the similarities and differences of the cases presented in this paper is illustrated bellow.

<table>
<thead>
<tr>
<th>CONTEXT</th>
<th>Location/Environment</th>
<th>Activity/Task</th>
<th>Personal/Interpersonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Växjö Library</td>
<td>□</td>
<td>☒</td>
<td>□</td>
</tr>
<tr>
<td>BoardFamily</td>
<td>☒</td>
<td>□</td>
<td>☒</td>
</tr>
<tr>
<td>FreerideHub</td>
<td>☒</td>
<td>□</td>
<td>☒</td>
</tr>
</tbody>
</table>

Table I. Use of different attributes of context information in our cases

With reference to the equation presented at the beginning of this paper, there are indications that attributes of context information can increase the value gained from information $V_g$ and hence increase in the overall value of information $V_i$. Increased value of information was based on providing content in context. Increased value of information was manifested in both of our cases with higher usability. The attributes of context information could be taken into consideration either manually or automatically during the design process. This input needs to be done with direct user involvement and without becoming annoying. We think that beside the technology advancement, contextualization as an aspect of the participatory could be used in order to increase the relevancy of the information and thus the value of it. This is mainly because the contextuality is an aspect of participatory approach since the context is defined by the users and is for the users.

Our further research activities will explore other dimensions related to contextual information such as location/environment, activity/task and personal/interpersonal instances of contextual information. These will be part of the efforts that we will conduct in two new research projects.

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DESIGNING AND IMPLEMENTING UBIQUITOUS LEARNING ACTIVITIES SUPPORTED BY MOBILE AND POSITIONING TECHNOLOGIES

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ABSTRACT
Recent advancements in mobile, wireless and positioning technologies have contributed to the development of new software applications to be used anywhere, anytime and in almost any device. When these technologies are used in educational settings, new learning opportunities arise. Location-based services in educational settings potentially offer advantages of tailoring the content to the specific location/object and thus contextually increasing relevance. In this paper we describe our current research focuses on exploring the integration of physical and computational media for the design of ubiquitous learning environments to support a variety of outdoors educational activities using mobile and positioning technologies. Moreover, we are also exploring how intelligent support techniques can be integrated in these environments, to scaffold particular aspects of teaching and learning.

KEY WORDS
Mobile learning, location based services, educational games, intelligent support.

1. Introduction
In recent years, the use of advanced computing and information processing techniques in educational settings has increased significantly [1]. Initially, the use of computer-based training, and later on networked-based learning, mainly due to the development of the World Wide Web, led to the definition of the concept e-learning. Advancements in mobile and wireless technologies have also had an impact in educational settings, thus generating a new approach for technology-enhanced learning called m-Learning (mobile learning). The rapid development of mobile technologies combined with access to content almost everywhere and every time, allows learners to gain new experience regarding learning in a variety of situations and not only in school settings. This latest view on technology-enhanced learning supported by wireless technologies and ubiquitous computing is referred as Ubiquitous Learning or u-learning [2] [3]. An important characteristic of u-learning is the introduction of two important features into the learning environment, namely context awareness and adaptivity. Context awareness and adaptivity have the potential for helping to support learning and teaching in new ways. By context awareness we mean that educational services and content that are provided to the learning environment should be aware of the situations in which the learner/s actually is/are. By adaptivity we mean that the different learning contents should be adaptable to the particular setting in which the users are.

In this paper, we explore how these two aspects can be integrated while designing and implementing ubiquitous learning activities supported by mobile and positioning technologies. This paper proceeds with a brief overview regarding the use of context in educational settings and it continues by describing a realistic scenario we have designed to test these ideas. This is followed by a section that briefly describes the pedagogical and educational implications of the described scenario. Thereafter, we described our technical approach and implementation of the ideas described in the former section. This paper concludes with a section discussing our expected results and future activities.

2. The use of context in educational settings
There have been numerous attempts trying to define what context is. Hull and colleagues [4] defined context as “aspects of current situation”. Another definition is given by Brown [5] where he defines context as “elements of the user’s environment which the computer knows about”. Another more precise definition of context is given by Dey and Abowd [6] where they define context as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”. Our view of context slightly differs for those definitions. We define context as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment”. Thus, our definition of context relies upon a three layer 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.
Winters and Price [7] claim also that the context in which
an activity is taking place is crucial for design.
Recent research within the field of location-based
services (LBS) suggests that LBS have the potential to
improve learning and therefore should be used in
educational settings [8]. LBS in educational settings
potentially would offer advantages such as tailoring
educational content to a specific location/object, thus
textually increasing relevancy, content generation and
adaptation resulting in a more personalized learning
experience [8]. These features of LBS have been recently
explored in problem-solving learning activities and in
educational games. Educational gaming applications,
according to Nova and colleagues [9], can be categorized
in two types: the first one is using tracing devices for
supporting collaboration while the second one is to use
the location as event triggers. The use of tracing devices
(GPS) can be found in a location-based called game
Savanna [10]. The Savannah game explores how
positioning technologies can be integrated into the
physical environment for exploring aspects related to
animal behavior in Africa. Other approaches regarding
the use of positioning techniques to support learning activities
can be found in games such as Mindwarping [11] and
ARQuake [12]. Those efforts mainly explored the
mapping of computer games onto real-world settings.
Our design approach regarding the use of location to
support learning activities slightly differs from those
implementations mentioned above. We focus not only on
providing content that is tailored to the specific
location/object but also by allowing learners to generate
content that is related to a particular place. In the
Savannah game, the limited field of activity was an area
defined by 90 x 60 m, while we are implementing our
activity regardless of space limitations. In a study
conducted by Winters and Price [7], they discussed a
separable view of the context information, suggesting that
the use of location as an attribute of contextual
information is not enough. Similar ideas were suggested
by Nova and colleagues [9]. Our approach is to explore
the potentials of tailoring the content to the specific
location/object and thus contextually increasing
relevancy, as well as content generation on the spot in
order to personalized learners’ experience. In connection
to digital content, we rely upon using rich content
repositories with well elaborated metadata scheme.
Overall, our design plan is to benefit from using location
information for context awareness and metadata
repositories for content adaptation. Having these ideas in
mind, we have developed a conceptual schema for the
implementation of our ideas. This architecture is
presented in figure 1 bellow. This conceptual scheme is
consistent with our three layer view of contextual
information discussed earlier. In the following sections of
this paper, we will describe each one of these blocks and
we will explain their purpose.

3. Scenarios as design rationale

The approach we are using for designing our activity is
scenario-based design. According to Carroll [13],
scenario-based design is a technique that belongs to a
complementary tradition that seeks to exploit the
complexity and fluidity of design by trying to learn more
about the structure and dynamics of the problem. This is
accomplished trying to see the design situation in many
different ways, and interacting intimately with concrete
elements of it. The main purpose of the scenario is to
provide a rich description of the different possible
interactions. The possibility for describing different types
of interactions in our scenario is crucial to design because
it will enable us to define best ways for content adoption.
Scenario-based design allows us also to investigate
multiple views of interaction between the users and the
information system, and interactions between the users
themselves mediated by the system.

3.1 Scenario

In this section we describe a specific educational scenario
based on the ideas presented in the former sections.
Based on Carroll’s [13] recommendations, scenarios
should have the following characteristics: setting, actors,
goals or objectives and actions and events. The context in
which the activity takes place is in a field study to be
conducted by 10 and 11 years old children as part of their
outdoor school activities. In this scenario, the teacher will
challenge the children to conduct a “treasure hunt” game-
like activity through the city. Smart phones, rich media
content deliver to mobile devices and location-based
services will be some of the technical ingredients that will
be used to support the different activities. The idea is to
design and implement a learning environment that enables
children to learn and to experience historical events in
their local environment in novel ways. As the activity has
a number of game-like components, aspects such a
competition, collecting points, measuring time
performance and strategies are embedded in this activity.
With regard to the recommendations suggested by Caroll,
we have defined the following characteristics for our
scenario:
**Setting** – In our case it is a city exploration.

**Actors** – children and teacher

**Goals or objectives** – Finding the hidden treasure and multidisciplinary learning (problem-solving)

**Action and events** – Represent the action that need to be taken by children in the different stages of the game

Below we describe in further details the educational flow and the scenario in which the activities will take place.

“Exploring and searching for the hidden treasure” scenario: Thirty two fourth grade children (10-11 years old) will participate in this activity. They are divided in eight groups and each group consists of four kids. Only one group will be conducting this activity at a time, therefore this activity will have eight sessions. Each pair of kids in each group will be equipped with a smartphone (Nokia 6630) for content generation and delivery (team A) while the other two children will be equipped with GPS enabled smartphone (HP iPAQ 6515) for navigational purposes (team B). Each group will be supervised by an adult (in our case, a teacher candidate from our university). While one group is in the field, the main teacher stays in the classroom with the rest of the class. The children need to document their activities using their smartphones during each stage of the “treasure hunt” activity.

Each group will start their tour in the city’s main square where the teacher candidate will explain the rules of the game. Previous to this activity, the kids were informed in the classroom very briefly about what will happen. In the major’s residence located in the city square there is a sign written with roman numbers describing the exact year when the building was built. Both teams need to go inside the building and to search for a visual identification tag of semacode1 type attached to one of the walls. Once the tag is identified, team A scans the semacode using the camera from the NOKIA phone. Almost, immediately, they will receive a text message sent from one of our servers. This information provides the basic guidelines describing how to decode and convert the roman numbers (under 500) into Arabic numbers. When team B performs a similar action scanning the semacode, group B will receive a set of instruction describing how to convert and decode roman numbers above 500. Some minutes later, both teams will received a text message that our system automatically sends to both groups containing the following question “The year that this residence was built is ______”. Children need to write an answer using their smartphone and submit it. If the answer is correct, the system sends the instructions describing how to proceed in the “treasure hunt” quest. It should be noticed that from a pedagogical perspective, the activity have been designed in a way that forces children to collaborate. In case that the answer submitted by the groups is not the correct one, the system sends an alert to the teacher who is supervising the entire quest, informing him/her that the children need some support. The teacher then uses a NOKIA digital pen to create some clarifying notes about Roman numbers. He/she sends those notes back to the kids in the form of a MMS. Once the children decode the year in which the building was built they get some new instructions. This information contains navigational instructions telling the groups how to reach the next goal “move 300 meters to the west, and after continue 150 meters north”. When they are in the proximity of the building (about 30 meters distance), the system generates the picture of the building that they need to visit in order to find the “ancient hidden treasure”.

When they enter the building they need to look for a new semacode and scan it. If the semacode is activated using the phone number from team A, our system transmits audio content that contains information about different Swedish Kings and the periods they ruled. When the semacode is activated from the phone number from team B, then our system generates a text message that contains information about the Swedish Kings and dates when they have been inaugurated. Our system is able to identify the request from each phone by relying upon the IMEI (International Mobile Equipment Identity, a number unique to every GMS and UMTS mobile phone) number of each phone. After the audio and text content are listened and read by children of both teams the following question arrives to their phones: “Which Swedish King ruled during the period in which previously visited building was built?” If the answer is wrong they get the opportunity to listen/read once more the audio and text material. If the answer is correct by both teams, then team A will receive multimedia content that contains a map describing where the next building is. Team B receives the picture of the next building in this quest. In case that both teams of children experience some troubles finding the route (10 minute delay), the teacher who is supervising the entire activity receives a trigger message from our system. The teacher uses then the digital pen and draws in the map the exact locations of the teams. When the children manage to find the next building, they need to enter and to look for and scan the third semacode. When team A scans the semacode, it will trigger a slideshow of pictures that visualizes different architectonical stiles. When team B activates the third semacode, they receive audio content that explains the different architectonical stiles. When both groups finish watching and listening to the materials, a new question arrives: “Which is the architectural stile of this building?” If the children are unable to answer the question, the system offers them the opportunity to review/listen the material once more. When both groups manage to solve this question, the system generates the last tip to each of them about whereabouts of the “hidden treasure”. The A team gets the message saying: “Behind the statue of King Gustaf there is one letter that contains the PIN code of the safe box.” Team B gets the picture of the map where the

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1 Is a 2D barcode tag for embedding URLs to specific location (source: [http://www.semacode.org/](http://www.semacode.org/)). Semacode tags can be read by a camera-enabled mobile phone.
safety box is place. The PIN code is written in roman numbers. All these settings and possible interactions are illustrated in the figure 2.

During each session of this educational game, children need to document their activities by taking photos of the historical objects. These actions will bring more points into the game. Points will be also scored according to the time when the pictures were taken. The time and geographical location where the pictures were taken can be extracted from the metadata associated with each picture. All these materials will be used by the children to reconstruct the entire event later on in the classroom. After all groups have finished their quest, all these activities will be represented in a map where the all the routes are displayed. This presentation is also accompanied with time needed for each group to finish certain stages of the session.

4. Pedagogical and educational aspects of the scenario

The scenario described in the former section offers a challenging arena for children to learn and to experience a variety of learning domains in novel ways. During the different stages of this activity, children need to use their mathematical (number conversion/decoding), historical (ruling period of different kings), art (architectural styles like baroque, rococo, renaissance etc.) and geographical/navigational (self navigation, map reading) skills for the successful accomplishment of the tasks that are part of the quest. In addition, group discussions and interactions, as well as collaboration are also activities that enrich the learning experience. The integration of all these different skills into a realistic scenario offer children a challenging learning environment. Challenge, curiosity, collaboration, competition and control are important factors to promote children’s learning in our scenario. According to Lepper and Malone [14] these are key factors for supporting intrinsically motivation.

The pedagogical approaches used for the design of the educational activities in our scenario are inspired by the ideas of social constructivism and collaborative knowledge building perspective [15] [16]. In our particular scenario, the role of teacher is to be a coach and to supervise the different activities. New knowledge can not simply be assimilated with the support of a more knowledgeable person (i.e. teacher), but also jointly constructed through solving problems and collaboration. In our scenario, challenge, concepts such as curiosity and competition are implemented by using game-like activities while control and collaboration are promoted by using intelligent support techniques. The different educational activities together with the technical solutions that constitute the different components of our system define an environment that can be classified as a ubiquitous learning environment.

During the entire process of the proposed activity, children will be constructing knowledge by active engagement while taking pictures and creating content that will be used later on in the classroom while reconstructing the different aspects of the educational game. The process of reconstruction and analysis in classroom settings is one of the advantages of location-based experiences for education [8].

5. Technical aspects and implementation

In the conceptual scheme presented in figure 1, we identified two main components. The first component is the content management that corresponds to the content repository block described in our conceptual scheme (figure 1). The second component is the intelligent support component that corresponds to the scenario generator presented in the figure 1. The content repository of our conceptual scheme is implemented using the Collect, Convert and Send (CSS) system. CCS is a software application we have developed in one of our on-going research projects. Since the devices used in our scenario allow children to create digital content on the spot, and this content is also a crucial part of the game, it is important to have access to a content repository with a flexible metadata scheme. A repository of this type has been now developed as part of our current efforts with our CCS system. These aspects will be described in the next section.

The intelligent support features described in the scenario basically correspond to the second block presented in our conceptual scheme. In our scheme, we referred to them as the scenario generator component. The intelligent support features of our system rely upon the use of artificial intelligent techniques. These intelligent features provide the opportunity to generate personalized content based on a specific location. Moreover, they will control the content flow between the content repository and the users, as well they as they will control the representation engine. In the coming section, we describe in more details all the components we have built and implemented.
5.1 The content repository

The CCS system has evolved from a software solution we developed in the MUSIS project (Multicasting Services and Information in Sweden, www.musis.se). In the MUSIS project we explored, identified and developed a number of innovative mobile services with rich multimedia content to be distributed over wireless networks in university campuses [17]. The CCS system includes a repository with metadata associated with the content that flows through the system. The CSS system is modular, reusable and easily expandable having the ability to deal with new types of content and technologies. The CCS can get the content from different sources, based on pre-defined rules, it can convert it to formats that are supported by mobile device, and then transmit it. These activities can be done automatically without human intervention. The CCS system is modular and it can easily be combined with intelligent support techniques. The CCS system architecture is illustrated in the figure below (see figure 3).

![Fig 3 – The architecture of the CCS system](image)

In our current efforts, we are using the CCS repository (number 1 in the figure above) to store the different types of content. The scheduler (number 2 in figure 3) will be used to trigger different intelligent support features that can initiate appropriate actions. This can be distributed via different channels (number 3 in figure 3). The content will be used to visualize the settings that are shared by users. This particular aspect may have the potential to enrich collaboration by opening a new channel of communication: communication through the artifact [18]. This communication will be achieved using different types of content, such as maps, short notes using digital pen and rich multimedia content.

5.2 The repository with metadata

In order to make the content metadata retrieval and storage transparent to the users, we have developed a number of technical solutions that automatically generate and collect the appropriate metadata. For instance, if a user takes a picture with his smartphone and thereafter, she/he will send it to our system, automatic metadata containing attributes such as GPS coordinates, time, IMEI number, etc. will be generated. Since in our scenario, users will take pictures of specific buildings, we will focus on the JPEG format. The JPEG format data is stored using embedded EXIF tags. EXIF stands for Exchangeable Image File Format, and is a standard for storing interchange information in image files, especially those using JPEG compression.

The process of metadata generation and extraction is illustrated in figure 4 below. The users in this case, school children, are equipped with a handheld device with GPRS access, a built-in digital camera and a GPS receiver (number 1) that takes a picture of a building (number 2). We developed an application that runs in the handheld device and automatically writes appropriate metadata into the header of the picture, in this case a JPEG file. After the file is transferred to the CCS system, metadata are extracted from the file (number 3). All metadata (e.g. GPS data, username, date, size of the file etc), are stored in the database (number 4) and the JPEG file is stored in the repository (number 5). A reference to the location in the repository is stored as a metadata in the database. All these metadata enables profiling of the content. Metadata extracted from the content can be categorized in metadata that describe location/environment attributes, metadata that describes activity/task and metadata that describe the person/group. Moreover, all these features (especially the GPS related metadata) allow a transparent communication with the representation component described in our conceptual scheme. One of the main advantages of this approach is that all the metadata are automatically generated. Manual metadata generation is a very time demanding and annoying task for the users and therefore it should be avoided. Metadata automatically generated will enable user clustering into certain categories that will enable content awareness [18].

![Fig 4 – The metadata extraction and generation](image)
5.3 Scenario generator

In the field of Computer Supported Collaborative Learning environments, actors (learners, teachers and resources) can be distributed both in time and space, what it creates numerous problems regarding how to make collaboration more effective. Our scenario shares some of these problems too. Similar problems in web based collaborative learning environment [19] has been successfully tackled using agent technologies and we think that intelligent support techniques can be used in our system as well.

The scenario generator block described in our conceptual scheme is used to offer a generality of use for our system. Thus, we expect that teachers will be able to implement different activities using the intelligent support mechanism offered by the scenario generator. In our case, users are children that will directly benefit from the information (output) that will be provided by the system. In order to illustrate these ideas, we present some “pseudo-code” [20] that can be used to create a specific scenario and its behavior. The idea of this “pseudo code” is to show how certain actions in the activity are triggered from specific events, time or user input. In the example below, EVENT has two entities LOCATION and BUILDING that are used to trigger agent’s actions. The LOCATION entity is triggered with the help of GPS values while the BUILDING entity is triggered by semacode activation. The internal TIMER (scheduler) is used to measure the time the time for the next action to take place. And ANSWERS represent user’s input.

```
WHEN EVENT
  BUILDING = {first semacode activated}
  Start timer
  Check IMEI number
    IF the IMEI number = A team
      THEN sent roman number
description document for numbers
<500
    ELSE sent roman number
description document for numbers
>500
  WHEN TIMER = {5 minutes}
    Sent question one
    IF ANSWER from IMEI = A team = B team = (1898)
      THEN sent instruction for the
second stage
      ELSE send SMS to the Teacher
      Teacher sends SMS with
instructions
  WHEN EVENT
    IF LOCATION = {<50 meters for the building}
      THEN sent picture of the building
  WHEN EVENT
    BUILDING = {second semacode activated}
    Check IMEI number
      IF the IMEI number = A team
        THEN sent audio material
      ELSE send text material
    Send question two
    IF ANSWER = {King Gustaf}
      THEN sent map to IMEI= A team,
picture to IMEI= B team
      ELSE retransmit the audio/text file
  WHEN EVENT
    BUILDING = {third semacode activated}
      IF IMEI= A team
      THEN sent slideshow
      ELSE sent audio material
      Send question three
      IF ANSWER = {Baroque}
      Check IMEI number
        IF IMEI number = A team
          THEN sent SMS
          ELSE retransmit the slideshow and audio
file
      SAVE the log file
END.
```

The kind of intelligent support described in this “pseudo-code” is achieved by a well crafted piece of software that performs certain actions that can be time or event triggered. In our scenario, location attributes are calculated both, manually (using semacode tags) and automatically, using the application we have developed to collect the GPS data. Thus, the proposed system and its implementation make use of location/attributes of the contextual information as defined in the first section of this paper.

5.4 Digital maps as presentation layer and spaces for reflection

The representation engine in our conceptual scheme described in figure 1 uses digital maps as a presentation layer. According to Benford [8], this is one of the advantages while learning is supported in this way. Due to the technical features of our system, it is possible for us to match a particular object type into the correspondent specific location in a digital map. Currently, we have developed a customized GoogleMap (http://maps.google.com) using the GoogleMaps API, combined with satellite pictures from the actual region the game is taking place. This particular aspect shows how the interdependency between layers of context information can be used to visualize data in contextual ways.

The children involved in the activities described in this paper can have a double role when it comes to content; they can act as content consumers and content providers. During special parts of the field activities, children receive already made content by the teachers or from an existing resource, while in other occasions they will be generating their own content. Once back in the classroom, the content that has been created by the kids can be reused, give them the role of content providers. Since all content has associated metadata, it will be possible to search on the database for pictures that match certain criteria from the repository (number 5 in figure 4). In the classroom settings, the customized GoogleMaps we implemented can be used as a representation engine to show the location where these pictures were taken and to represent the route that the children took during the course of the game. All these aspects will enable further exploration of the topics learned in the field leading to interesting discussions and reflections based on the children former experiences.
6. Conclusion and further work

This paper described our on-going efforts regarding the design and technical implementation of ubiquitous learning activities supported by mobile and positioning technologies. From a technical perspective, using our three layered structure of contextual information we have implemented a system to support ubiquitous learning. Our ongoing efforts will include the evaluation of our concepts and technologies, both from a technical and a pedagogical perspective. For the evaluation purposes, we will conduct several on-site trials with 32 children in one of our local schools during June 2006. We will assess the usability and usefulness of this particular location-based educational game, so we can learn which concepts can be integrated into school activities and which aspects demand further exploration. In future stages of our efforts, we plan to make advance use of historical dependencies and to investigate the potential of these ideas for increasing the relevance of the content for different user’s settings. Moreover, we will extend our trials as part of our efforts within the scope of two European projects.

References

Exploring How Pervasive Computing Can Support Situated Learning

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Abstract: Pervasive computing offers new ranges of possibilities when it comes to supporting learning and collaboration. The design of educational activities in these environments is a challenging task that raises the question of how pervasive computing can be used to support new modes of collaborative learning. In this paper we discuss those aspects related to the design of situated learning activities supported by pervasive computing and the collaboration modes that may emerge as a result of these activities. Additionally, we discuss how activity theory can be used as a framework for designing such educational activities. We present the results of a trial we conducted while introducing pervasive computing in an elementary school activity. In conclusion we open the discussion about the relation between the design of innovative learning activities supported by pervasive computing and new collaboration possibilities that may arise in these environments.

Keywords: collaborative learning, situated learning, pervasive computing, activity theory, ubiquitous learning environments

1 Introduction

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 [1]. 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 [2]. The idea that new technologies will transform learning practices has not yet been fully realized, especially with regard to technology-facilitated collaboration. The task of designing effective computer support along with appropriate pedagogy and social practices is more complex than imagined. The use of advanced computing and information technology in educational settings has increased significantly during the last decade. The rapid development of these technologies combined with access to content almost everywhere and every time, allows learners to gain new experiences regarding learning in a variety of situations and not only in school settings. This latest
view on technology-enhanced learning supported by wireless technologies and pervasive computing is referred as pervasive learning. These technologies offer new possibilities for designing innovative educational activities that can be carried out indoors, outdoors, and in any place. The design of such activities is especially challenging when it comes to conceptualizing how pervasive technologies can be used to support collaborative knowledge building.

According to Hansmann and colleagues [3] the principles of pervasive computing are: decentralization, diversification, connectivity and simplicity. These principles imply that the mobility of users and the presence of heterogeneous devices with a high level of usability in the learning environment open opportunities for innovative educational practices. Thus, in the context of our efforts two main research question have been identified, How can pervasive technologies be used to support new ways of learning about different educational subject matters, and how can these technologies support groups of learners when they, collectively, share their understanding of such a material?

In this paper we discuss those aspects related to the design of novel educational activities supported by pervasive technologies and the collaboration modes that may emerge as a result of learning in these environments. The paper is structured as follows; section 2 discusses those ideas related to situated learning and pervasive environments while in section 3 we discuss how activity theory can be used as a framework for designing new collaborative learning activities and for understanding those collaboration modes that may arise as a consequence of these actions. In section 4 we present the results of a trial we conducted using pervasive technologies with elementary school children working together across two locations, indoor and outdoor respectively. Section 5 concludes the paper by discussing the relation between the design of innovative learning activities supported by pervasive technologies and new collaboration possibilities that may arise in these environments.

2 Situated Learning and Pervasive Environments

Situated learning [4] 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 that typically involve a problem or task, other persons, and an environment or culture. 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 [5]. But it is not the abstraction of knowledge as such that distracts learners, but that the abstractions are not illuminated with examples in context. Understanding is a product of the context and activity. 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 [1]. Yet an authentic context alone is not sufficient to support students’ learning. Situated cognition argues that learners must engage in authentic tasks as well.

Designing technology support for situated learning is a challenging task, since in many cases technology tends to shift the learning environment to a more computer based representation moving away from the core ideas of situated learning [6], [7]. However, pervasive computing opens new dimensions to avoid this diversion, by
providing means to trustfully representation of learners’ contexts by placing them back into the authentic. Pervasive environments provide the possibilities of embedding computational support for the learning activity in the learner’s physical and social contexts [8]. These embeddings can offer new challenges when it comes to design interaction models to support a variety of collaborative learning situations. Embedding learning activities into the learner’s physical and social context is consistent with the core ideas of situated learning. Understanding the role of context in pervasive computing for learning is an important factor in the design and analysis of these systems. In the next section we explore how Activity Theory can be used as a design tool to overcome some of these problems.

3 Activity Theory as a Framework for Supporting Situated Learning with Pervasive Technologies

Activity Theory (AT) is a philosophical framework that allows the study of different forms of human practice [10]. Activity Theory can also be used to provide a broad conceptual framework in order to describe the structure, development and context of tasks that are supported by a computerized system. It is the authors’ belief that this can provide a model for the design and evaluation of interactive learning environments supported by pervasive technologies. Bellamy [11] suggests that interactive technology can promote educational change because, according to activity theory, artifacts mediate human activity. Activity Theory has been used successfully in designing human-computer interactions for learning activities [10] and more recently used in the design of mobile learning [12], [13].

The reason to use AT is that it has a simple form to represent concepts such as role, rules, and tools, which have important impacts on learners’ activities. Moreover, AT also maps the relationships amongst the elements that are identified as having influence on human activity. In our particular case, we applied AT for guiding the design of an interactive learning environment that used pervasive technologies to support a number of indoor and outdoor educational activities that were performed by different groups of children.

Each of the indoor and outdoor groups can be regarded as a semi-independent activity system that was a subset of larger activity system that encompassed these two groups. This larger activity system required the indoor and outdoor groups to collaborate in order to accomplish a specific learning task (See figure 1). Using this model expanded from Engeström’s activity system [12] provided us with a tool for design and a foundation for later evaluations giving us insight and record of the history of actions between the different groups. The division of labor was a key point of for how we explored new interaction modes to promote collaboration. In the coming section we describe a specific educational scenario based on the ideas presented in the former sections together with the technologies we used for its implementation.
4 Bridging Indoor and Outdoor Educational Activities Using Pervasive Technologies

4.1 Educational Activities

Thirty 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 this activity 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 kids. Additionally, each group was divided in two subgroups of five kids each, where one subgroup was working indoors in the museum while the other group was outdoors. Only one group was conducting this activity at a time, therefore this activity had three sessions. The outdoor subgroup was equipped with three smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding visual semacode1 tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. Each group was supervised by a couple of adults (in our case, teacher candidates from our university). 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 pervasive technologies in a variety of ways.

Together with the teachers and our designers, we developed a set of activities conceived 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. The activities were

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1 Is a 2D barcode tag for embedding URLs to specific location (source: http://www.semacode.org/). Semacode tags can be read by a camera-enabled mobile phone.
designed containing challenging problems to be solved by the children where they needed to apply problem-solving strategies, to understand the rules, and to collaborate. Figure 2 illustrates some of the activities conducted by the different groups. One of the main pedagogical challenges of such game-based activity was to design learning activities that fostered children’s collaborative problem solving skills within the same subgroup across the different locations.

**Figure 2** Bridging indoor and outdoor activities.

During the different stages of these trials, children needed to use their mathematical (number conversion/decoding), historical (state of main square through history), and geographical/navigational (self navigation and historical map reading) skills, as well as negotiation abilities 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.

### 4.2 Technical Aspects and Implementation

In order to provide technological support for the activities described in the section above, we developed and implemented the solutions that are illustrated in figure 3. The activities for the outdoor subgroup in the mobile environment (see left side of figure 3) were supported by 4 smart phones used as tools for collaboration, communication and for creating, receiving content, and controlling the activity. 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, for reading the 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 for generated content. The last smartphone was used as a device for controlling the content related to the specific tasks and activities. The indoor subgroup located at the museum was equipped with a desktop computer with Internet access and a mobile handset for still photography.
children in this subgroup participated in the game utilizing a customized web based application we developed. The game activities 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 3. The ACS had a direct connection to our content repository (number 3 in figure 3) 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.

![Figure 3](image)

Figure 3 *The technical solutions used for supporting the activities*

### 4.3 Educational Activities, Pervasive Technologies and Collaboration Modes

As already mentioned, most of the activities in this game were designed in such way to impose the division of labor, thus forcing the subgroups to collaborate. Moreover, in order to add more realism to the game an adult performing as a blacksmith from past centuries provided some historical background, so that the children in the square needed to share this information using pictures with the children at the museum, thus giving a new contextual dimension to this information. Table 1 describes the entire activity flow of the trials. The activities are classified into those that happened outdoors and indoors and they are linked by the collaboration mode used by the children in order to bridge these situations.
Table 1. Collaboration modes for bridging indoor and outdoor activities in our trial

<table>
<thead>
<tr>
<th>Outdoor Activity</th>
<th>Collaboration Mode</th>
<th>Indoor Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying the object and taking pictures of roman numbers</td>
<td>Communication and negotiation using pictures and instant text messaging (IM)</td>
<td>Decipher roman numerals</td>
</tr>
<tr>
<td>Interpretation of audio content</td>
<td>Communication using instant text messaging (IM)</td>
<td>Understanding historic audio content</td>
</tr>
<tr>
<td>Taking pictures of buildings in the main square</td>
<td>Collaboration using instant text messaging and pictures</td>
<td>Comparing pictures with an old picture of the square for identification</td>
</tr>
<tr>
<td>Meeting the blacksmith</td>
<td>Collaboration with the museum to identify the tool that does not belong to the picture. Communication using pictures and instant text messaging (IM).</td>
<td>Identifying the tool that does not belong to the picture from the blacksmith table</td>
</tr>
<tr>
<td>Back in history in the cooper plate to hear the story of found coins</td>
<td>Communication between the subgroups using instant text messaging (IM)</td>
<td>Calculating how much the treasure is worth today</td>
</tr>
</tbody>
</table>

In this way, this particular activity offered children the possibility 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

According to Jonassen and colleagues [8] meaningful learning will take place when learners are engaged in the type of activities described above.

5 Discussion and Future Efforts

Situated learning as a theory for knowledge acquisition is based on the idea that learning activities should be embedded in authentic contexts. Traditional computer-based applications can be seen as moving real life situations a step further away from the authentic, thus pushing situated learning opportunities out [6][7]. Pervasive technologies can provide the necessary means to promote situated learning, as they allow enhancing the learners’ context by the creation of embedded ubiquitous environments in realistic settings. In the case we have illustrated, pervasive technologies served as a bridge to connect children working with the same activity context in distinctly different locations, as well as they served also as a tool to support collaborative activities.

From a design perspective, Activity Theory can function as a useful instrument to guide the design process of innovative educational activities. In our trial, the subjects were children placed at two locations that needed to communicate and to collaborate
through an object to fulfill a specific task. The division of labor promoted the collaboration between children in order to achieve the game objectives. Our future efforts will include the evaluation of our concepts and technologies, both from a technical and a pedagogical perspective. During the rest of 2007 we will conduct several on site trials with different classes from our local schools. We will assess the usability and usefulness of this kind of pervasive learning environments with a special focus on collaborative learning, so we can learn in more depth which concepts can be integrated into school activities and which aspects demand further exploration.

6 References

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 semacode1 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 problemsolving 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 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).

Fig 1. Starting the game

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.

![Fig 2. Roman numerals](image)

When both subgroups successfully answered this question, they proceeded to the third mission of the game. The task here was to identify a building located close to the main square using a historical photograph as a reference. The indoor group received the reference photo and their task was to identify what the building looks like now. To accomplish this mission they needed to collaborate with the outdoor subgroup sharing photos taken with the mobile phone and exchanging information via IM (see figure 3). After they came to an agreement, the outdoor subgroup needed to scan the semacode on the selected building to continue.

![Fig 3. Identifying the old building](image)

This triggered the fourth mission where the outdoor group needed to meet with a blacksmith (a real person representing a character from the 19th century) who had a stand in the local square market. The task for the outdoor group was to identify which one of the tools in the blacksmith’s stand did not belong to that historical period. In order to solve this task they needed to negotiate with the indoor group by exchanging photographs and using the IM functions. The final mission was to go back to the location where the game started and to listen a story of valuable coins found there some centuries ago. The indoor group needed to answer how much the treasure would be worth today. In order to accomplish this task the children in the museum needed to communicate with the outdoor group while this could be performed using instant messaging.

### 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 children needed to perform. In the mobile environment, two of the smartphones were running the Nokia Raccoon2 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

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2 Application developed by Nokia Research Center which makes it possible to run an web server on Symbian phones [http://research.nokia.com/research/projects/mobile-web-server/](http://research.nokia.com/research/projects/mobile-web-server/)
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.

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
The 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

Bridging outdoors and indoors educational activities in schools with the support of mobile and positioning technologies

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Abstract: In this paper we present our design approach for bridging outdoors and indoors learning activities with the support of mobile and positioning technologies. In order to illustrate these research efforts we describe the outcomes of two trials we have conducted with more than fifty elementary school children. The activities presented in this paper aspire at supporting the notion of situated learning with mobile and positioning technologies to promote new ways of collaboration based on the users’ learning context. The results of our experiments indicate that children enjoyed learning where mobile devices are used in situ, supporting the learning activities in the context of which they are taking place.

Keywords: situated learning, collaboration, ubiquitous and mobile learning, design-based research.

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1 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, changing the ways we communicate and collaborate. In the context of this paper we will refer to these technologies as Ubiquitous Computing Technologies. Educational environments are being subject to these changes providing an opportunity for curriculum development that can use these socially based devices for supporting different aspects of learning and teaching. Mobile and wireless technologies enable the opportunity to interact in new ways with the physical world as they allow allocating computational power and interaction away from the limitations of desktop computers. From this perspective, learners are given the opportunity to collaborate in new and interactive ways within the physical world, as well as the physical world can be augmented through digital technologies. These facts provided innovative ways of interacting with the environment, but also present design opportunities for multiple kinds of collaboration to support different aspects of the learning process (Price et al., 2003). There is now a challenge of how best to design learning activities enhanced by ubiquitous computing to support new forms of collaboration.
In this paper we describe our on-going efforts regarding the design, implementation and evaluation of innovative educational activities supported by ubiquitous computing technologies that have been carried out in the context of our project AMULETS (Advanced Mobile and Ubiquitous Learning Environment for Teachers and Students). Our research efforts are an attempt to provide a generic framework for designing learning activities supported by mobile and ubiquitous technologies. We aim at exploring new collaboration and interaction patterns that may arise as a consequence of integrating physical and computational media through the design of ubiquitous learning environments. These novel learning environments aim at supporting different outdoors educational activities that can be combined with the actual school curriculum.

In the rest of the paper, we will describe in further details the theoretical, conceptual and design aspects of our research activities, as well as the results we have obtained. We present a brief explanation in relation to the technologies and applications we have developed. We will conclude by discussing the outcomes of the trials in connection to design as well as the direction of our future research activities.

2 Learning, context and ubiquitous technology support

The rapid development of ubiquitous technologies combined with access to content almost everywhere and every time, allows learners to gain new experience regarding learning in a variety of situations and not only in school settings (Denk et al., 2007). This latest view on technology-enhanced learning supported by wireless technologies and ubiquitous computing is referred as Ubiquitous Learning (Rogers et al., 2005; Syvānen et al., 2005). Ubiquitous learning environments offer new possibilities for bringing computational support into the context of learning and present a challenge regarding the integration of mobile context-aware computing in these new educational settings (Tamminen et al., 2004). Context information that brings into account features such as the user’s location and/or his/her activity/task and his/her profile can be crucial for enhancing the users’ experience and the collaboration modes in which learning activities occur (Uden, 2007). Adding context awareness to these new artifacts can increase their usability and offer new ways of user interaction and experience (Loke, 2006).

Our specific field of research includes topics related to contextual information, digital content, positioning and mobile services in connection to supporting situated learning (Lave and Wenger, 1991). Recently, there have been numerous approaches and prototype implementations exploring the potential of contextual services in ubiquitous learning environments. Contextual services have been developed and implemented by Ogata et al. (2005) to support collaborative learning activities in ubiquitous computing environments in the context of the TANGO (Tag Added learNinG Objects) project. This system provides learners with tagged based information about the objects in his/her surrounding based on the learners’ profile using location and environment attributes of the context in which learning takes place. Another example regarding the use of ubiquitous technologies in a contextual way can be found in an outdoor learning environment for ecology developed by Rogers et al. (2005). The main idea of the Ambient Wood project was to design and use new forms of digital argumentation for woodlands learning in field studies having in mind environmental and location attributes of the learning context.
The use of location-based services (LBS) in educational settings potentially would offer advantages such as tailoring educational content to a specific location/object, thus contextually increasing relevancy, content generation and adaptation resulting in a more personalized learning experience (Benford, 2005). These features of LBS have been recently explored in problem-solving learning activities and in educational games. Educational gaming applications, according to Nova et al. (2005), can be categorized in two types: the first one is using tracing devices for supporting collaboration while the second one is to use the location as event triggers. The use of tracing devices (GPS) can be found in a location-based called game Savanna (Facet et al., 2004). The Savannah game explores how positioning technologies can be integrated into the physical environment for exploring aspects related to animal behavior in Africa by providing the students with the ability to recreate and experience animal life in outdoors settings.

Our research in this direction differ from those efforts described above due to the fact that the design of our activities focuses on supporting situated learning with ubiquitous computing technologies to promote collaboration based on educational content and the users’ location and activity. To this end, we need a well-articulated conceptual design framework with sufficient detail to match the opportunities and constraints of mobile and ubiquitous technologies to the possible range of novel collaborative interactions. More specifically, we are proposing a general design framework that might best be characterized as socially situated, problem-oriented learning in authentic and collaborative settings. This conceptual design framework is presented in more detail in the coming section.

3 Conceptual framework

Situated learning 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 that typically involve a problem or task, other persons, and an environment or culture. Within the socially situated learning perspective (Lave and Wenger, 1991), learning is viewed as an active process of knowledge construction in which learners are typically involved with other learners in authentic, problem-solving situations. The need to learn created by a realistic problem provides motivation, and interaction with other similarly immersed learners provides facilitation. 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 the learning (Brown et al., 1989). But it is not the abstraction of knowledge as such that distracts learners, but that the abstractions are not illuminated with examples in context. Understanding is a product of the context and activity. 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 (Brown and Duguid, 2000).

There have been numerous attempts trying to define what context is, Hull et al. (1997) have defined context as “aspects of current situation”. Another definition is given by Brown (1996) where he defines context as “elements of the user’s environment which the computer knows about”. A more precise definition of context is given by Dey and Abowd (2000) where they define context as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”. Our view of context slightly differs from those definitions. We define context as “information and content in use to support a specific activity (being individual or collaborative) in a
Bridging Outdoors and Indoors Educational Activities in Schools with the Support of Mobile and Positioning Technologies

A particular physical environment. Therefore, our definition of context relies upon a three-pole 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. Winters and Price (2005) claim also that the context in which an activity is taking place is crucial for design.

Figure 1 makes an attempt to illustrate the ideas described above, while using them as the basic components of a conceptual framework for designing ubiquitous learning activities. A central 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 that learning activity is taking place. The learners interact with the LAS and with each other, thus promoting different modes of collaboration. Each one of the three attributes described in figure 1 can be combined in a 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.

Figure 1 A Conceptual Framework for Designing Ubiquitous Learning Activities

The surrounding circle of this conceptual framework basically defines the context where the activities are taking place. The Learning Activity System is the central component and provides the technological support for the collaboration between learners in the context that these learning activities are taking place. According to our view, 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 indoor and outdoor activities and collaboration.
Taking a different perspective regarding previous research in the field of Computer Support Collaborative Learning, our research focus is concerned with novel ways of using ubiquitous technologies to support a range of different collaborative combinations rather than to focus mainly on one form of collaboration around the computer screen. Specially, our focus is on designing new ways of interaction between learners, and learners with objects in the physical world mediated by ubiquitous technologies. This approach enables learners to interact more freely and engage in a variety of interaction and collaborative modes depending on the context in which learning occurs.

4 The AMULETS project

In the AMULETS project we are exploring how teachers can develop and implement novel educational scenarios combining outdoors and indoors activities that use ubiquitous computing technologies together with stationary computers. Fifty five elementary school children have performed outdoor activities equipped with Smartphones, PDAs and GPS devices in the field of natural sciences, history and geography. The educational scenarios consisted of different stages with game like features. At the end of the outdoors learning sessions, all these activities can be reconstructed in the classroom using several visualization tools, including among others digital maps. 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, argumentation, collaboration and reflection.

Since June 2006 we have conducted two trials (described in detail in section 6) using educational scenarios that were designed together with teachers to support the regular school curriculum. In the first trial the theme of the scenario was learning about “tree morphology” and in the second trial “the history of the city square through centuries”. In the forest scenario conducted in the spring 2006, twenty-six fourth grade students (10-11 years old) took part working in 7 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 identifying different types of trees, measuring the height and age of trees. 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. Part of the children’s tasks was to record still images and video 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.

In the city square trial conducted in the fall of 2006, twenty-nine 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 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 related to the square’s history supported by animated characters available in the smartphones provided the background information and the challenges. Children needed to work together in order to solve the missions
including deciphering Roman numerals and finding locations for historical buildings and providing activities on history, geography, and culture. In these two trials the design of the different ubiquitous learning activities was guided by the main ideas of the conceptual framework presented in section three. The table below illustrates how the different attributes of our conceptual framework were applied in these two different cases.

### Table 1  Applying our Conceptual Framework

<table>
<thead>
<tr>
<th>Trial</th>
<th>Location / Environment</th>
<th>Task / Activity</th>
<th>Personal / Interpersonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergunda School</td>
<td>Field activities were complemented by Pre and Post Activities conducted indoors</td>
<td>Exploring trees and their environment</td>
<td>Bridging the indoor and outdoor activities was supported by using digital maps as presentation layer</td>
</tr>
<tr>
<td>Växjö Square</td>
<td>Activities were conducted simultaneously both in indoor and outdoor settings</td>
<td>The history of city square through centuries</td>
<td>Collaboration between indoor and outdoor activities was supported by using text and rich media</td>
</tr>
</tbody>
</table>

### 5 Design and implementation of ubiquitous learning activities

In this section we present in details the design and implementation of a couple of learning activities using ubiquitous technologies. First we describe those methodological aspects that guided our design activities. We continue by presenting the different scenarios of the trials. We conclude this section by providing a detailed description of the technological aspects related to our implementations.

#### 5.1 Methodological Considerations

Designing technology support for ubiquitous learning and collaboration requires new frameworks and practices to implement and evaluate these systems. In recent years, educational researchers have given increased attention to research questions and aspects that may influence practice. These design activities have been adopted by researchers, as part of their research endeavours (Edelson, 2002). These efforts include, among others things, the design of educational activities, software, and school–community collaborations. This approach to research, characterized by iterative design and formative research in complex real world settings has been variously referred to as design experiments (Brown, 1992), developmental research (Richey et al., 2003), and lately as design-based research . 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 (Hoadley, 2004). 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.
The design of the scenarios was guided by the principles of scenario-based design (Carroll, 2000) emphasizing a clear definition of the settings, actors, objectives and actions. The physical settings of both trials were primarily located in outdoor environments and the 4th & 5th grade children can be considered as the actors. The concepts and educational content used in the scenarios has been developed with the help of two teachers and this activity was integrated into the school curriculum. Each one of the trials has been organized as a set of tasks or missions that children needed to complete. The design process was an iterative loop consisting of two stages. The first stage was the design of the first trial scenario in which we tested how to bridge indoor and outdoor activities sequentially. The second stage started with a new trial where we tested how to bridge indoor and outdoor activities simultaneously. Detailed descriptions of the activities and goals of these two stages are presented in more detail in the coming sections.

5.2 The Trials

Both 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 children’s collaborative problem solving skills within the same subgroup and with their peers. Most of the activities were designed in such way to promote the division of labor, fostering collaboration, first within subgroups in both trials and then across the groups in the second trial. In order to add more realism to the activities we had adults performing as a scoutmaster in the forest for the first trial and a blacksmith from past centuries provided additional historical background in the second trial. During the different stages of these trials, children needed also to use of their mathematical (number conversion/decoding), historical (state of main square through history), environmental (types and ages of trees) 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 quests. 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. In the following subsections we describe in details the activities that took place in both our trials.

5.2.1 Bergunda school trial

This first trial took place in the outskirts of the Bergunda School (near Växjö, Sweden) in the surrounding nature in the spring 2006. Students were divided into six groups and each group was roughly four children. The activity was conducted in six sequential sessions with each group. The students in each group were equipped with a smartphone (Nokia 6630) for event triggering (semacode1 reading) and content delivery. They also had a GPS enabled smartphone (HP iPAQ 6515) for navigational purposes and content generation and documentation.

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1 Is a 2D barcode tag for embedding URLs to specific location (source: http://www.semacode.org/). Semacode tags can be read by a camera-enabled mobile phone.
Bridging Outdoors and Indoors Educational Activities in Schools with the Support of Mobile and Positioning Technologies

The activities were divided into three stages including a pre-activity, a field activity and a post activity (figure 2). The pre-activity comprised a series of lectures about the forest that were carried out by the teacher in the classroom setting during several days. During this stage children learned about different aspects of the forest and basic knowledge that could be used to identify the trees in the nature. 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. At the end of the workshop, children got the first task to solve. A short film with several animated characters displayed in the smartphone gave the children a description of their first mission. The children needed to go to the closest forest located 200 meters southeast from the school yard in order to identify a particular kind of tree (among three possible choices) that corresponded to the specific one presented during the pre-activity at the school.

Figure 2 Bergunda School trial activities

In order to solve this task, the children needed to scan the correct semacode tag attached to the right tree. Each one of the three trees had a different semacode an in case of an incorrect choice of tree, additional information was delivered to the smartphone giving the children new information to solve the task. This exploratory and task based activities continued encouraging the children to learn how to measure the height and age of surrounding trees. During the entire field activity the children documented their activities by taking photographs and video. At the end of these two days event, all children were gathered together in the classroom. The post activities took place in the classroom where all groups presented and discussed the content created during the trial while this content was tailored to a specific location.

5.2.2 Växjö square trial

This trial took place at the main square and at the museum of history in the city of Växjö in the fall 2006. The overall activity was divided into three sessions over two days. The students were divided in three groups, each group consisting of ten 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.

The outdoor subgroup was equipped with three smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding the visual semacodes tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. Teacher students supervised the groups during the activities. 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.

The main activity of this trial was carried out in the form of a collaborative game-like activity that was organized as a set of missions taking place in different locations and across different time periods related to local and regional history. The activities were designed around the group collaboration to solve the challenges for each task. 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 characters 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. These activities are illustrated in the figure 3 below.

**Figure 3** Växjö square trial activities

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 Governor’s building located in the main square. The collaboration started when the outdoor subgroup sent a photograph of the Roman numerals to the indoor subgroup. The discussions and negotiations about deciphering the Roman number have been supported by a mobile instant messaging (IM) we used for this purpose. After the children decided which was
the correct answer for the Roman numerals task the outdoor subgroup scanned the correct semacode and the second mission started. In case the wrong semacode was selected, they received additional information giving them new clues. The remaining missions explored cultural events from the start of World War II, the changing geography of the city square in the 19th century, the market and goods sold in the 18th century and concluded with a medieval treasure found buried under the square. All these activities required collaboration and negotiations activities between the children in both subgroups.

5.3. **Technological Overview**

In the technical architecture presented in figure 4, we identified three main components. The central component is the **Learning Activity System** that is comprised of three main functional blocks, namely the Activity Generator, the Collaboration Tools, and the Presentation Engine. The Activity Generator contains the Activity Control System (ACS) and the Collect, Convert, and Send (CCS) system. The ACS is a software application that controls the flow of the learning activities. The ACS promotes the collaboration between the users and devices while retrieving and storing the content. The CCS 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 to inside through instant messaging, images, and video.

**Figure 4** The technical architecture of the Learning Activity System
The Presentation Engine provides the visualization tools to support reflection in the post activities through the use of metadata and rich media content generated during the group activities. 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.

In the outdoor activities children have used smartphones and PDAs with GPS capabilities to interact, create, collect, and communicate throughout the learning activities. These devices exchange data with the LAS components retrieving and sending content and information, as well as they interact with the sensors. For the indoor activities the children interacted through a web interface linked to the Presentation Engine, thus providing contextual content and connection to activities performed by the outdoors group.

In the first trial the focus was on designing the activities sequentially for a proof of concept. The content in each mission had spatial associated metadata which helped us to recreate the flow of these activities providing spaces of reflection and visualization using digital maps. For instance, when a child took a photograph with his/her smartphone, metadata containing attributes such as GPS coordinates, time, and phone id was automatically attached to the EXIF format of the JPEG picture and then sent to the CCS. All these features have been used to reconstruct the actual fieldwork in classroom settings. Furthermore, we could help children to visualize the specific place in which an activity took place or visualizing the path taken by a particular group in a map. These features were implemented using AJAX and the Google maps API in order to exchange and visualize data stored in our repository, as illustrated in the Presentation Engine described in figure 4.

In the second trial, the learning activities were designed in a way to explore collaboration between children on a peer-to-peer, peer-to-group, and on a group level. Due to the constrained space of the square, we relied upon using semacodes in order to determine the location of the events. The activities for the outdoor subgroup in the mobile environment were supported by four 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 children needed to perform.

In the mobile environment, two of the smartphones were running instances of the Nokia Racoon software, an application developed by Nokia Research Center which makes it possible to run a mobile web server on Symbian phones (please see http://research.nokia.com/research/projects/mobile-web-server/). Nokia Racoon has a built-in python script for enabling mobile text communication via instant messages. One of these smartphones was used for mobile instant text messaging and the second phone was used as the controller for the LAS, linking the content delivered and created by the group. All the content generated by the children contained contextual information such as group number, activity type and additional information and it was stored in the CCS. The
indoor subgroup located at the museum participated in the game utilizing a customized web based application we designed for this purpose.

6. Assessment and analysis

The main goals of our assessment were twofold; firstly, to explore how children experience these ubiquitous learning activities and secondly, to look at usability aspects related to these technologies in educational contexts. In both trials we used several techniques for data collection including questionnaires with the children, interviews with the children and teachers, observations and data stored files. The questionnaires were used mostly to evaluate usability aspects while the interviews with children and teachers where used to evaluate more the pedagogical related aspects of the trial. Data collected during the trials and saved on the CCS repository have been used 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 trial the server log files has been used to trace the messages exchanged between the indoor and outdoor subgroup to investigate the collaboration that happened between these subgroups.

6.1 Questionnaires

Questionnaires were conducted with the children after both trials in order to collect some information that will give us some indications concerning the usability of the technological solutions we developed. During both trials we conducted 55 questionnaires exploring aspects such as perceived ease of use, satisfaction and peer collaboration mediated by ubiquitous technologies. From the 26 children that attended the first trial, 22 of them described the activities as “very enjoyable” while the other four described them as “enjoyable” only. One important aspect to mention is that none of the respondents described the activities as boring and uninteresting despite that they have such option in the questionnaire. In the second trial the situation was a little bit different: 18 children described the activities as “very fun” while 11 described them as “fun”. Also in this activity none of the respondents described the activities as boring or uninteresting.

From the 26 students that participated in the first trial 17 of them found the use of ubiquitous technologies as “very easy to use” while the other eight in the same question answered with “easy to use”. Only one child described the mobile technology as “not easy to use”. In the second trial the usability questionnaire for the technology was made separately for the indoor and outdoor subgroup since they used different technological tools. From 29 students that participated in this trial, 14 of them belonged to the outdoor subgroups while 15 to the indoor groups. Eight of 14 children from the outdoor subgroup described the smartphones as “very easy” to use while the other six describe them as “easy”. From these 14 only four of them described the use of semacodes as “very easy”, nine of them described as “easy” and only one described the use of semacode as “difficult”. Eight out of 14 children described the picture taking software in the mobile phones as “very easy”, three described as “easy” and the other three have not provided they answer. Six out of fourteen students described the instant messaging service used as “very easy”; the other six describe it as “easy” while the last two didn’t answer this question.

The children participating in the indoor subgroups had access to a web application and to an instant messaging service. From the 15 children participating in these
subgroups, eight of them described the web application as “very easy” to use, 6 of them described as “easy” while only 1 found it “difficult” to use. Eleven out of fifteen children described the instant messaging system as “very easy” to use, three of them described it as “easy” to use while only one found it “difficult” to use.

Table 2 Questionnaire breakdown

<table>
<thead>
<tr>
<th>Satisfaction</th>
<th>Very Enjoyable</th>
<th>Enjoyable</th>
<th>Less enjoyable</th>
<th>Un-enjoyable</th>
<th>Unanswered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 (26)</td>
<td>22</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Trial 2 (29)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Fun</td>
<td>Fun</td>
<td>Less fun</td>
<td>not fun</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perceived Ease of Use</th>
<th>Very easy to use</th>
<th>Easy to use</th>
<th>O.K. to use</th>
<th>Hard to use</th>
<th>Unanswered</th>
</tr>
</thead>
<tbody>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Smartphones</td>
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<td></td>
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<tr>
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<td>8</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Semacode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2 Outdoor (14)</td>
<td>4</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Picture taking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>8</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Instant messaging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2 Outdoor (14)</td>
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<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<td>Web application</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial Indoor (15)</td>
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<td>6</td>
<td>0</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Collaboration in group</td>
<td>Excellent</td>
<td>Good</td>
<td>Not so good</td>
<td>Bad</td>
<td>Unanswered</td>
</tr>
<tr>
<td>Trial Outdoor (14)</td>
<td>9</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Trial Indoor (15)</td>
<td>13</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Collaboration across groups</td>
<td>Excellent</td>
<td>Good</td>
<td>Not so good</td>
<td>Bad</td>
<td>Unanswered</td>
</tr>
<tr>
<td>Trial Outdoor (14)</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Trial Indoor (15)</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

From 14 children participating in the outdoor subgroups 9 of them described the collaboration between them as “very good” while the other 5 described it as “good”. When asked about the collaboration with the indoor subgroup, only 4 of them defined it as “very good”, 8 of them defined it as being “good” and 2 described it as “not so good”. 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. When asked about the collaboration with the outdoor
subgroup, five of them described as being “very good”, seven of them described as being
“good” and one child thought that this collaboration was “not so good “ and the other
“bad” respectively. Also here, one child did not answer this question.

6.2 Interviews

Interviews were also conducted with two teachers that participated in these trials in order
to explore educational aspects and pedagogical impacts of using and designing the type of
activities described in section 6. Interviews were also conducted with five children
(randomly chosen) who participated in the Växjö square trial.

The teachers’ general impression was that the trials were successful and they both
felt that ubiquitous technologies, smartphones in the case of these trials, may help
children to become more engaged in the activities (See excerpt 1.). 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.

**Excerpt 1.** Teacher interview:

> I think it is good to use everyday technology that the children are used
to, like the mobile phones. It was really fun for the children, they get
more engaged in the activities and it is in their world.

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 events that took place in different time periods. 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 subgroup. It appears that weather
conditions can affect the way that children received and processed the different pieces of
information

The second question we asked was, “Which missions do you remember from that
day?” It appears that the children remembered the missions with real characters (like the
blacksmith) rather than missions where the content that 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 would 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 coherently remember 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.

**Excerpt 2.** Student interview:

It was a fun day. Helping one another in different places with the group work. It worked well with the messages and chatting to my team members. I will gladly do similar activities again.

### 6.3 Data stored files

Data stored files provided us with another resource for assessing what happened in the second trial due to the collaborative nature of the activities. These files contained messages transmitted by all three groups during the different collaborative activities, as well as the time when they were sent. The information that we present below refers to the collaboration that happened in the scope of the Roman numeral task only. The first group participating in the trial was composed of boys and used the instant messaging tool relatively often during this particular mission. Based on server registrations the time difference between the first and last instant message was 24 minutes. During this period of time the outdoor and indoor group exchanged 11 instant messages.

The second group consisted of girls only and they used the IM tool during 16 minutes. In total they sent 12 messages to each other during this period of time. A sample conversation from what actually happened when this task took place is presented below:

**Excerpt 3.** Data Transcript:

**MOBILE GROUP** 2006-12-06 11:39:59
When was the residence built?

**BASED CAMP** 2006-12-06 11:41:39
We got your pictures.

**MOBILE GROUP** 2006-12-06 11:42:35
Letters MDCCCLXVIII

**MOBILE GROUP** 2006-12-06 11:43:34
The year is 1848

**BASED CAMP** 2006-12-06 11:44:19
What do you see for an alternative question?

**MOBILE GROUP** 2006-12-06 11:45:43
1840 or 1912

**BASED CAMP** 2006-12-06 11:47:20
It is 1868

**MOBILE GROUP** 2006-12-06 11:48:09
OK

**BASED CAMP** 2006-12-06 11:48:44
No, this is 1848

**MOBILE GROUP** 2006-12-06 11:49:39
We know
The third group was also composed of boys and used the IM tool for 26 minutes. During this time they exchanged 19 instant messages.

6.4 Analysis

In general, 73% (40 out of 55) of all children described their participation in these activities as “very enjoyable” and 27% (15 out of 55) of them described them “enjoyable”. Based on these results we can see that in general children had a very positive attitude towards learning in these kinds of environments. From a technical perspective, the solutions we have implemented and tested in these two trials were quite robust and not major problems were identified. From the data we collected from the questionnaires with the children, the majority of them found the different technical solutions easy to use and only in a few cases children experience some difficulties.

When it comes to looking at how teachers experienced these trials, in general they felt that the activities were successful, as they could combine traditional learning in the classroom and outdoors in new ways using ubiquitous technologies. The use of these technologies outside the classroom was considered to be beneficial but at the same time both teachers felt that there is some risk of the technology overshadowing the learning process. 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 through the activity where key components, helping the children to learn social and problem solving skills embedded in the history curriculum. Looking at design related issues, the two teachers enjoyed being actively involved in the design of the activities as well as in the process of creating new learning materials. They also experienced that this type of ubiquitous learning activities may work out best when there is a proper balance between pre and post classrooms activities combined with field trips.

We looked at the data stored files collected in the second trial in order to see if there were some similarities regarding the collaboration patterns between the different subgroups while solving the same task. Below in table 1, we present a breakdown of the instant messages exchange between the groups while they were collaboratively solving the Roman numeral task. Based on the analysis of this data, it can be observed that the most engaged group in collaboration and communication using the instant messaging system was the third group, while the second group was more efficient in solving this task collaboratively using the instant messaging system. The analysis of the files indicates that the first and third group exchanged about twice as many informal messages then the second group. Together with the questionnaires and interviews this points to the importance of carefully designing collaborative problem-solving tasks in which all members of a group are actively involved.

<table>
<thead>
<tr>
<th>Table 3 Collaboration figures on the Roman numeral mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Group 1</td>
</tr>
<tr>
<td>Group 2</td>
</tr>
<tr>
<td>Group 3</td>
</tr>
</tbody>
</table>
In the girls group almost 67% of the messages exchanged between the indoor and outdoor subgroup has been related to solving the task, while in other two groups this was 36% and 31% respectively. Initial analysis of these data store files raises important questions about the utilization of our conceptual framework to design collaboration in context especially when it comes to support informal communication.

7 Discussion and conclusions

The activities and results presented in this paper contribute, in our estimation, with new knowledge and perspectives related to the design of ubiquitous learning activities using mobile and positioning technologies. The outcome of our efforts suggests that outdoors 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

According to Jonassen et al. (2000) meaningful learning will take place when learners are engaged in the type of activities described above. 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.

Traditional computer-based applications can be seen as moving real life situations a step further away from the authentic, thus pushing situated learning opportunities out. Ubiquitous technologies offer new possibilities to promote situated learning, as they allow enhancing the learners’ context by the creation of embedded ubiquitous environments in authentic settings. The implementation of the conceptual framework presented in section three of this paper provides a model for designing novel learning activities that offer new possibilities for exploiting the benefits of contextual information combined with alternative ways of interaction and collaboration. These contextual collaboration modes serve as a bridge to connect children working with the same activity context in distinctly different locations, as well as they served also as a tool to support authentic learning activities. Our view on collaborative authentic learning activities outside the classroom have been guided by the ideas of Rogoff and Lave (1984) that suggested that young people and adults learn more efficiently, and perform more competently in realistic settings outside the classroom than they do in many decontextualized environments that school usually provides (see also an elaboration of learning in context by Brown et al., (1989)).

Bridging the outdoor and indoor activities in our trials was performed in different ways. In the Bergunda school trial we bridged the outdoors and indoors activities by using digital maps as spaces for the reconstruction and visualization of what happened in the field. These ideas are in line with current research conducted by Benford (2005) that indicates the benefits of being able to recreate the scenarios back in the classroom by having access to the data collected during the field trips. In the second trial conducted at the Växjö square bridging the outdoors and indoors activities was done simultaneously and supported by a number of collaboration tools. The collaboration was mediated by the
use of an instant messaging application (text mode) and a photo sharing application (pictorial mode). These different collaboration tools provided new ways of interaction between children, independently of their physical environment.

The results of our trials indicate that children were open and positive when it comes to using ubiquitous technologies 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 subgroups in the Växjö square trial where the location and environmental attributes of the context affected the overall performance. 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 ubiquitous 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.

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 reasoning, argumentation and reflection. 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 asses if this technology facilitates the ways people interact with mobile phones and the objects compared with the visual tags solutions we have been using until now. 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 these trials. We will continue our efforts in this direction in conjunction with our ongoing research activities that will take place during the rest of 2007 and the beginning of next year.

Acknowledgments

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References


Bridging Outdoors and Indoors Educational Activities in Schools with the Support of Mobile and Positioning Technologies


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

Figure 1. A conceptual framework for collaboration in context

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

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

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 sub-sections 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*
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

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

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

Figure 4. Teacher student trial activities

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>
<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 at 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>
<td></td>
</tr>
<tr>
<td>Växjö Square</td>
<td>The main activity was conducted both in indoor and outdoor settings at Local museum and town square</td>
<td>Parallel and simultaneous tasks about the history of the square and live in past times Co-located</td>
<td>Collaboration between indoor and outdoor groups was mediated using text and content mode</td>
<td>Peer-to-Peer Individual-to-Group</td>
<td></td>
</tr>
<tr>
<td>University</td>
<td>The main activity was conducted both in indoor and outdoor settings at University lab and surrounding nature</td>
<td>Parallel and simultaneous and shifting roles. Tasks about tree morphology and the ecosystem Co-located</td>
<td>Collaboration between indoor and outdoor groups was mediated using text and content mode</td>
<td>Peer-to-Peer Individual-to-Group</td>
<td></td>
</tr>
</tbody>
</table>
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

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

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

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

Figure 5. The technical architecture of the learning activity system
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

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-

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.

Figure 6. Mapping digital content with associated metadata in the 3rd trial.
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

The properties of mobility and context need to be refined in order to accommodate the learning opportunities presented by the new mobile technology. 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>
<thead>
<tr>
<th>Context / Environment</th>
<th>Evaluation Type</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location / Environment</td>
<td>Learning Opportunity</td>
<td>Field Indoor, Outdoor Remote &amp; Co-Located, Survey, Interviews</td>
</tr>
<tr>
<td>Task / Activity</td>
<td>Impact on Task</td>
<td>Usability, Survey, Observations</td>
</tr>
<tr>
<td>Personal / Interpersonal</td>
<td>Impact on Social Processes</td>
<td>Collaborative, 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>
</tr>
</tbody>
</table>

Table 2. Assessment framework
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 then 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.

Figure 7. Usability
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

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

Figure 8. Collaboration in trial 2
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

Figure 9. Value of collaboration in trial 3

<table>
<thead>
<tr>
<th>Value of Collaboration in Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
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<td>3</td>
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<td>4</td>
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<td>6</td>
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<td>7</td>
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</tbody>
</table>

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 focus of this activity was based on the identification of plants and the measurement of soil temperature, light, and moisture. 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.
Collaboration in Context as a Framework for Designing Innovative Mobile Learning Activities

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 sub groups 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-
volved 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

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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


Context modeling to support the design of mobile learning
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ABSTRACT
The evolution of information and communication technologies in the last three decades has had an impact in all aspects of human activities. Learning has also been subject of these changes. Current research efforts in the field of mobile learning have been in many cases guided by a learner-centered approach. Context awareness and content adaptivity are crucial components in mobile learning environments. One important challenge is how to design and implement technological tools and methods to support them. In order to tackle this challenge, learners’ context should be defined. In this paper, we describe our current efforts regarding how to model context in mobile learning activities. We introduce a time dependent context model based on a three pole structure that can be used to design and support context awareness in mobile learning environments. We illustrate its applicability in four different cases where mobile learning activities and implementations have been guided by the use of this model.

Categories and Subject Descriptors
K.3.1 [Computers and Education]: Computer Uses in Education – collaborative learning, computer-assisted instruction (CAI), computer-managed instruction (CMI), distance learning

General Terms
Management, Design, Theory,

Keywords
Mobile learning, context model, context awareness, content adaptivity, contextual data model.

1. INTRODUCTION
Technological development has had a strong impact in the way people learn. This can be noticed especially due to a large number of implementations of technology enhanced learning environments over the last two decades. These implementations have primarily been led by different pedagogical approaches that mainly were rooted in constructivist learning theories.

These theories have been based on two main streams: cognitive constructivism (derived form [20] work on theory of knowledge) and social-cultural constructivism (derived from [27] work on cognitive psychology). Moreover, as suggested by the work of [8], the main component of the constructive learning view could be summarized as the “learner actively constructs knowledge” in interaction with material systems, discussion with other participants and reflection upon concepts in the specific domain. Brown and Duguid [4] complement this view by defining learning as a social activity that is primarily based on collaboration. Collaboration can occur between actors (i.e. learners) and with the help of artifacts [10]. Recent mobile learning projects have primarily focused in developing new tools (primarily based on mobile devices) that can enhance the collaboration and knowledge acquisition. Such cases can be found in some of the projects described by [23]. The common denominator of these projects is the tendency for the adoption of a true learner-centered design approach. These trends emerged mainly because due to rapid evolution of the mobile (i.e. personalized) technologies. For achieving fully learner-centered environments the use of context awareness and content adaptivity is crucial, as suggested by [22]. Mobile learning environments offer new possibilities for bringing computational support into the context of learning and present a challenge regarding the integration of mobile context-aware computing in these new educational settings [25]. In these situations, achieving context awareness is crucial for supporting true learner-centered activities. Context awareness offers opportunities to embed learning in natural environments [21]. Content adaptivity enables the reusability of learning content in different settings (i.e. learning contexts). Therefore, the main research question to be discussed in this paper is formulated as follows: “How can context be used as a design input for supporting awareness and content adaptivity in mobile learning environments?”

This article describes a context model that tries to address those issues connected to context awareness and content adaptivity in mobile learning environments. This paper proceeds further by discussing those issues related to learning and context. Furthermore, it continues with the presentation of a context model that could be used as a tool to support the design of mobile learning activities. This is illustrated by presenting a couple of empirical examples that have been designed and inspired by this model. In the concluding remarks, we suggest how the development of a data schema inspired by this context model could be used to support content adaptivity.
2. LEARNING AND CONTEXT

Success in achieving learner-centered approach in technology enhanced learning implementations is intimately related with considerations regarding the learners’ context. Research has increasingly indicated that the inability of students to apply concepts learned in formal contexts is in many cases due to the abstraction and decontextualization of the learning [3]. But it is not the abstraction of knowledge as such that distacts learners, but that the abstractions are not illuminated with examples in context. The importance of context in mobile learning era has been highlighted by work conducted by [9] where he finds that context is one of the factors that can be used for categorizing mobile learning. Understanding and learning is a product of context and activity. Moreover the importance of context in knowledge creation and learning was suggested by the work of [18] where he suggests that knowledge creation (thus understanding) is directly affected by context. Moreover, situated cognition argues that learning is simplified by embedding concepts in the context in which they will be used [4]. This clearly indicates the importance of considering context for technology enhanced learning implementations. But despite this, defining context has been and still is a challenge. Different authors have attempted to tackle this challenge by providing numerous definition of context. For example, [11] defined context as “aspects of current situation”, which is a very broad definition. Another definition from a computational perspective is given by [5] where he defines context as “elements of the user’s environment which the computer knows about”. Another human centric definition of the context is given by [7] where they define context as “any information that can be used to characterize the situation of entities (i.e. whether person, place or object)”. [26] defines context as a combination of environment, activities and participants. While in mobile learning community context is defined as “context should be seen not as a shell that surrounds the learner at a given time and location, but as a dynamic entity, constructed by the interactions between learners and their environment” [24]. The wide variety of approaches to define what context is indicates its complexity. Moreover, the problem of context awareness in learning activities can not be tackled only from the definitions perspective. In the next section, we try to develop our own definition of context, followed by a model that describes this effort.

3. CONTEXT MODELING

According to [6] modeling is “an activity, a cognitive activity in which we think about and make models to describe how devices or objects of interest behave”. Therefore, the main idea behind models is to ease the understanding of complex phenomena.

![Figure 1. Relation between real and conceptual world in scientific methods](image)

The heterogeneity in the definitions of context illustrates its complexity; therefore the creation of a model would potentially be beneficial. The link between “real world” and “conceptual world” is based primarily on models [6]. This interconnection is illustrated in figure 1. Context is a real world phenomenon that needs to be understood for being able to provide support for context awareness. Context observations lead toward definitions, which should be accompanied with analysis that would eventually result in models. These models should facilitate the understanding of context, but still detailed enough so it could be used to predict (i.e. show awareness for) phenomena (i.e. context). Having in mind the idea behind modeling and different context definitions, we have defined context slightly different, and accompanied it with a model representation. Our definition is leaded form the activity perspective that is scalable to computational attributes. Thus, we define context as “information and content in use to support a specific activity (being individual or collaborative) in a particular physical environment at a specific time”. Our definition of context relies upon a three-pole structure. The three-pole structure consists of the following attributes: location/environment attributes, activity/task attributes and personal/interpersonal attributes and this placed in a certain time. 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 of mobile learning activities. Figure 2 makes an attempt to illustrate our context model applicable to mobile learning. The time dimension shows the changeability of context in different moments (represented as frames in figure 2). Time becomes important especially when it comes to historical dependencies as suggested by [13].

![Figure 2. Conceptual context model for designing learning activities](image)
basically defines one frame of context where the activities are taking place. The frame is defined by a time snapshot. Therefore context as complex phenomena is represented as a series of time differentiated frames.

From a technical perspective, the implementation of the Learning Activity System relies upon the use of different software components and mobile technologies, as well as sensors in order to contextually support different learning activities and collaboration.

Inspired by dimensional analysis in mathematical modelling, we consider that this approach can be applicable for context modelling as well. According to [15], dimensional analysis is defined as “a method by which we deduce information about a phenomenon from the single premise that the phenomenon can be described by a dimensionally correct equation among certain variables”. Therefore our context model can be described by terms of dimensional analysis. Dimensions of context are defined by three pole structures and time. The time dimension becomes important especially when it comes to historical dependencies that could affect user profile (i.e. personal/interpersonal attributes), activity and its location/environment. The space part of our context model (i.e. context frame of our conceptual model) built upon the three-pole structure can be represented by coordinate axis as illustrated in figure 3. Each axis represents one of the attributes of our conceptual model of context. It should be noticed that this represents just one snapshot (i.e. frame) at a certain time (t1).

![Figure 3. Dimensional analysis of context](image)

If we perceive the context of learning activity as a spatial function and we use the three pole attributes of the context, then the mathematical representation of our context definition can be expressed according to the following function:

\[ f(X_{LE}, Y_{PI}, Z_{AT}, t) \]

This basically means that context is a function of location/environment attributes (\(X_{LE}\)), Personal/Interpersonal attributes (\(Y_{PI}\)) and Activity/Task attributes (\(Z_{AT}\)) and time. While one frame of our conceptual model illustrated in figure 2, represents time integration of this function. Thus if the context function is represented by \(I(X_{LE}, Y_{PI}, Z_{AT}, t)\), one context frame could be defined as:

\[
\int_{t_{j-1}}^{t_{j}} f(X_{LE}, Y_{PI}, Z_{AT}, t) dt
\]

Where \(j\) values can vary between 1 and n. Therefore, one frame of this conceptual model is represented as a function that is time independent. This function could be represented as:

\[ g(X_{LE}, Y_{PI}, Z_{AT}) \]

Each frame of the contextual model could be represented as function of \(X_{LE}\), \(Y_{PI}\) and \(Z_{AT}\) complex variables. Each of these complex variables is functions of sub variables as well. These dependencies are presented in the table 1:

<table>
<thead>
<tr>
<th>Context</th>
<th>(f(X_{LE}, Y_{PI}, Z_{AT}, t))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location/Environment</td>
<td>Personal/Interpersonal</td>
</tr>
<tr>
<td>(X_{LE}) = longitude, latitude, building, humidity, temp., light int., etc.</td>
<td>(Y_{PI}) = person, group age, membership, collaboration, etc.</td>
</tr>
<tr>
<td>Location/Environment Axis</td>
<td>Activity/Task</td>
</tr>
<tr>
<td>(Z_{AT}) = type, rules, subjects inv. outcome, division, etc.</td>
<td></td>
</tr>
</tbody>
</table>

As this table shows, the context is basically comprised of infinite dimension that could be grouped in three major (location/environment, activity/task and personal/interpersonal) functions. McCarthy [17] also claims that context dimensions are infinite. Each of these sub variables basically represents a computational instance that is retrievable by the means of sensors and actuators. Today trends in mobile technologies tend toward embedding capabilities of different sensors and actuators into single device. This scale of integration enables new computational paradigm to emerge based on users’ context. Therefore using this dimensional representation of context, it is possible to use this model as design input for providing context awareness support.

4. USING CONTEXT AS DESIGN INPUT

Our main research efforts in the area of mobile learning have been designed and developed as a part of two research projects namely: MUSIS and AMULETS. The MUSIS project was designed to explore, identify and develop a number of innovative mobile services with rich multimedia content to be distributed over wireless networks in university campuses. In the AMULETS project we are exploring how teachers can develop and implement novel educational scenarios combining outdoors and indoors activities that use ubiquitous computing technologies together with stationary computers. As a part of these two projects we have run several trials related to learning across different contexts.
These trials took place during the last two years period and included trials with knowledge workers (i.e. librarians), primary school children and students.

4.1 Växjö Library trial
Ten librarians at Växjö Public library were equipped with Nokia 6630 smart phones with 128MB and with GPRS access (free of charge) to the MUSIS channels (including text, audio and video material) for a four weeks trial during the period October-November 2005. We used different data gathering techniques in order to identify and define the contextual attribute which would be used as design input for development of the new mobile service. Based on questionnaires, interviews and observations, it was evident that librarians spend most of the time while providing information regarding the content of the books to users. The contextual attribute used here was division of labor between librarians so they can offer better services to their users. Having in mind this, a audio book review service was developed that enabled librarians to share their book experiences with their fellow colleagues. This was done by the means of mobile multicasting of audio content. In general after the trial librarians were positive about the audio book reviews service.

4.2 Bergunda School Trial
The second trial took place at Bergunda School (near Växjö, Sweden) in the surrounding nature in the spring 2006. Students were divided into six groups and each group was roughly four children. The activity was conducted in six sequential sessions with each group. The students in each group were equipped with a smartphone (Nokia 6630) for event triggering (semaphore reading) and content delivery. They also had a GPS enabled smartphone (HP iPAQ 6515) for navigational purposes and content generation and documentation. The activities were divided into three stages including a pre-activity, a field activity and a post activity. The pre-activity comprised a series of lectures about the forest that were carried out by the teacher in the classroom setting during several days. During this stage children learned about different aspects of the forest and basic knowledge that could be used to identify the trees in the nature. The children needed to go to the closest forest located 200 meters southeast from the school yard in order to identify a particular kind of tree (among three possible choices) that corresponded to the specific one presented during the pre-activity at the school. In order to solve this task, the children needed to scan the correct semaphore tag attached to the right tree. Each one of the three trees had a different semaphore and in case of an incorrect choice of tree, additional information was delivered to the smartphone giving the children new information to solve the task. During the entire field activity the children documented their activities by taking pictures and making videos. The post activities took place in the classroom where all groups presented and discussed the content created during the trial while this content was tailored to a specific location. The contextual attributes used as design input where location and division of labor.

4.3 Växjö Square Trial
This trial took place at the main square and at the museum of history in the city of Växjö in the fall 2006. The overall activity was divided into three sessions over two days. The students were divided in three groups, each group consisting of ten 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. The outdoor subgroup was equipped with three smartphones (Nokia 6630) for content delivery, content generation, instant messaging and decoding the visual semacodes tags. The indoor subgroup was equipped with a laptop computer equipped with a GPRS connection and a mobile handset for still photography. Teacher students supervised the groups during the activities. 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.

The main activity of this trial was carried out in the form of a collaborative game-like activity that was organized as a set of missions taking place in different locations and across different time periods related to local and regional history. The activities were designed around the group collaboration to solve the challenges for each task. The contextual attributes used as design input in this trial were also: location and division of labor.

4.4 Teacher students trial
This trial took place on campus at Växjö University in the spring of 2007. 17 teacher students participated, divided into 4 groups. Each of these groups was divided into 2 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 semaphore tag and 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 4 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 texts in order to determine with the support of a tree taxonomy instrument to which family the tree belongs to 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 sessions between them, enabling all the students to experience the different roles and aspects of the trial. In this trial we tried to scale down the number of devices and control the communication to be more effective.

4.5 Applying the context model
The main idea behind applying our context model is the possibility of identifying certain sub variables that could lead to the design and development of contextual activities, thus resulting in a kind of context awareness support from the system side. Use of context as a design input has been suggested by different authors especially when it comes to defining user centered systems [2]. Technology enhanced learning systems represents a user centered system, the use of context as a design input would probably improve learners’ experience, thus potentially resulting in truly learner-centered approach. Except for the first trial (that took place inside, in the workplace), in the other trials the physical location of the users affected the design of the learning activities. Location played the important role while designing learning activities.The learning content has been generated in a way that its meaning was tailored with the location of the users. The tailoring of learning content was done with the help of
sensors (mainly visual codes and GPS data). In the first trial, the main design input was derived from the librarians’ activity (i.e., activity/task attributes). Audio book reviews system was built upon the fact that most of the time while working librarians’ spent offering information to users about content of the book. In the other trials, beside location (location/environment attributes) also activity/task attributes (i.e., division of labour) was also used as a design input. The division of labour served as a collaboration catalyst. In general, the model described in the previous section was helpful for identifying and dissecting context attributes, thus enabling them to be used as a design input. Usage of context attributes as a design input for technology enhanced learning represents a first step towards achieving context awareness in mobile learning settings. For detailed elaboration of these trials, including details of technical implementation please refer to our previous work [14].

5. CONTENT ADAPTIVITY
Nowadays, mobile devices have reached a very high level of hardware embeddings. Under these circumstances, every mobile learner has the potential of becoming a content creator. During our trials, most of the learners have created different types of digital content. The need for that content to be categorized for later reuse is evident. A typical way for doing this was using metadata structures. Manual metadata generation is a time demanding and annoying task for the users and therefore it should be avoided [28]. Having this in mind, we should try to embed as much as possible metadata automatically, based on the sensor data available (like GPS, temperature, date, time etc.). Using the three pole attribute of our context definition, it is possible to build a taxonomy for the categorization of learner generated content. In this way, the reuse of content should be based on the context. Main idea behind adaptivity in the systems relies only in the adoption of the database content [31]. For achieving context awareness there is a need for something more, there is need for semantic reusability of content. Therefore for content adaptivity there is a strong need for content “semantic personalization” that would be based on the context. The context model described earlier potentially enables this approach of adaptivity. Each frame of a contextual model represents basically a fully described XML document, consisted of four nodes. Three nodes represent the three pole structure while the fourth node of the XML file represents the snapshot attribute (i.e., date and time). The data structure based on the context model is designed according to XML schema illustrated in figure 4. The XML Schema provides a method to create precise descriptors that enable unambiguous declaration of data and their attributes. This enables semantic reusability of content based on contextual metadata. Therefore the context data model can be used as metadata that accompanies the content (such as pictures, audio files, video files, document etc) that can be shared and distributed in the mobile learning activities. Using metadata for context capturing has been advocated also by the work of [15] where they argue that context-based metadata could improve and enhance movement and transmission of the content. Having a structural organization of the context model based on the three-pole structure, as metadata for different types of content can support and enhance the collaboration between participants in mobile settings. Thus enabling active knowledge creation based on collaboration supported by content adaptivity and reusability.

Figure 4. Context XML Schema.

6. CONCLUSIONS AND FURTHER WORK
Context awareness in learning systems can be perceived as an interactive model between learners’ and services, and their definition is usually based on an ontological perspective [30]. Our context model complements this view by applying a dimensional analysis perspective that dissects the complexity of the learning context into a set of attributes that can be used as an input for the design of mobile learning activities. Recent research conducted by [12] has identified “location” and “time” as the most important parameters for describing the learners’ context. Our context model relies on a three pole structure that besides “location/environment” and “time”, brings also into account attributes such as the user’s activity/task and his/her profile. The outcome of our efforts suggested that applying the different context attributes of the model (such as “division of labor”) as a design input seemed to be important for enhancing the learners’ experience. The use of the “division of labor” attribute as a design input primarily served as a collaboration catalyst among learners. The organization of learning content packages is another important issue to consider while supporting context awareness in mobile learning environments. Balatsoukas and colleagues [1] claims that “the lack of concrete specifications can impede interoperable exchange of content packages” is the main problem in this field. The context XML Schema derived from our context model could be used as a tool for organizing metadata, thus potentially enabling semantic reusability of these content packages. Awareness in mobile learning implementations requires that learning activities are embedded into the learners’ context. Having this in mind and inspired by our context model, we can suggest some initial recommendations to support context awareness in mobile learning:
• Learning and exploration should be placed in authentic settings (i.e., location/environment)
• Collaboration should be promoted by the active construction of knowledge (attributes from learners’ activities/tasks should be part of design input)
• Content used and created during these learning activities should be enhanced with contextual metadata for allowing sharing and reusability

In the coming two years, we will continue to explore and further develop our current line of research as part of a new research project in which we will investigate how the ideas of seamless learning and “open inquiry” can be supported by features of context awareness and content adaptivity.

7. REFERENCES

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