Contextualised
Mobile Media for Learning

(Gecontextualiseerde
Mobiele Media voor Leren)

Contextualised
Mobile Media for Learning

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CONTEXTUALISED MOBILE MEDIA FOR LEARNING

Tim De Jong

SYNOPSIS

In today's Knowledge Society, information is exchanged over large distances and across time zones. This worldwide exchange was revolutionised by developments in the early 1990s that led to the global expansion of the Internet. Yet another revolution led to the rise of mobile technology that made communication independent of place and time. In a society where knowledge and communication play such an important role, the knowledge workers have to make an effort to constantly keep up-to-date; learning becomes lifelong and can be tightly integrated with daily life and work. In an effort to stay ahead of the competition, governments and companies recognise the need for lifelong learning support with ICT technologies.

In this thesis, we investigate the use of mobile devices to support lifelong learning. First, the current state-of-the-art in mobile social software for learning is explored and classified. Using the results from the literature review, a mobile extension to the Learning Network model for lifelong learning is described. A technical framework is developed on the basis of technical requirements elicited. The developed software was evaluated in the application domains of second language learning and building engineering.

Three empirical studies were carried out as part of the research in this thesis. The studies evaluated the use of several forms of lifelong learning support with mobile devices. The results of these studies not only suggest that the application of mobile support is beneficial for learning, but also that learner behaviour can be influenced using mobile devices. Furthermore, we found that learning in authentic real-world settings is influenced by a number of factors, some of which are different from traditional learning.

Voorwoord

Toen ik vier jaar geleden aan mijn baan bij het CBS begon, had ik mijn plannen om te promoveren al een tijdje in de ijskast gezet. Groot was de verrassing toen er opeens een reactie van de Open Universiteit te Heerlen kwam op een sollicitatiebrief die ik een half jaar eerder had gestuurd. Van het een kwam het ander, en dus mocht ik na maar drie maanden CBS alweer kennis maken met een nieuwe werkplek. 1 April 2006 begon mijn promotieproject, en op de eerste dag werd al meteen duidelijk dat ik voortaan een aardig woordje Engels zou moeten spreken. Ik was lange tijd namelijk de enige Nederlander/Limburger in het gezelschap van nieuw gestarte promovendi. De eerste maanden bracht ik door op een kamertje op de derde verdieping waar ik al met de eerste collega's kennismaakte. Daarna kwam ik met de andere aio's op een grote kamer "The Apecage" terecht, die in de vier jaar van het promotietraject een gezellig thuishonk vormde. Er brak een tijd aan waarin veel gereisd werd voor conferenties, de Winterschools en Europese projecten; ik heb nog nooit zoveel mensen in zo'n korte tijd leren kennen. Naast deze vele reizen was de sfeer in de Apecage ook altijd bijzonder goed. Er werd ook regelmatig naast het werk afgesproken en zo introduceerden we elkaar in de gebruiken, taal, politiek, en lekkernijen van onze thuislanden. Maar ook voor werkgerelateerde zaken konden we bij elkaar terecht; door het goede persoonlijke contact hielpen we elkaar vaak met technische, wiskundige of andere problemen of het recenseren van elkaars artikels. Het zijn dus vier interessante jaren geweest waarin ik veel geleerd heb, zowel op persoonlijk, sociaal, als vakinhoudelijk gebied. Ik ben blij met het eindresultaat en kijk uit naar de nieuwe uitdagingen op professioneel gebied die 2011 ongetwijfeld zal gaan bieden. Als laatste wil ik graag iedereen bedanken die een bijdrage aan dit proefschrift heeft geleverd.

Tim De Jong,
Januari 2011

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CHAPTER 1
Introduction

INTRODUCTION

In today's society, knowledge is the most important asset. In a globalising economy information is traded across time zones, language barriers, and international borders. It is not surprising then, that in the global knowledge society communication has become increasingly important. The commercialisation of the Internet in the mid 1990s revolutionised the global exchange of information by simplifying communication and cooperation over large distances. During the early days of the Internet, yet another technological development led to the up rise of mobile technology, especially mobile phones, that made communication and cooperation independent of place and time. The development of the networked society into this mobile society is most interestingly illustrated by Rheingold (2002), who along with the technological developments describes the power of mobile technology for the creation of ad-hoc transient communities, which he calls "Smart Mobs". With this specific example, Rheingold exemplifies how the use of a new tool can influence and change human behaviour and cognition.

The influence of mobile devices on our daily lives in particular and society at large increases as they are used more and more often and for more and more purposes. Castells, Fernández-Ardèvol, Linchuan Qiu, and Sey (2007) report that wireless communication, in the form of mobile telephony, was on the rise worldwide in the mid 1990s until in 2003 a milestone was reached, when for the first time there were more mobile-phone subscriptions than mainline subscriptions. The increase in mobile phone usage led to rapid developments in mobile technology, towards mobile computing devices encompassing more than communication alone. Modern mobile devices run complex operating systems that provide their users with simple ways to augment their functionality by installing third-party applications. Most of these devices also offer access to information from a variety of sensors, like for example a GPS location sensor, a compass, and an accelerometer. Thus, the current generation of mobile devices allows its users to carry out a multitude of increasingly complex actions ranging from the professional such as planning meetings, sending e-mails, planning the route to the next customer, to the more lifestyle-oriented, personalised actions such as playing games, listening to music, and browsing the Internet. In addition, these so-called smartphones are becoming more and more common. In May 2010, for example, 46% of the traffic accessing advertisements provided by AdMob was generated by smartphones (AdMob Mobile Metrics, 2010). More importantly, the increased use and the wealth of functionality offered by current mobile devices, leads to an increased need for mobile data access. Several sources already report an increase in mobile data access in the last few years and project a further increase in the coming ones. For instance, AT&T reports that its mobile data traffic increased 4932% from the second quarter of 2006 until the second quarter of

2009 (Megna, 2009). Likewise, CISCO, a large producer of wireless solutions, expects mobile data traffic to increase 66 times by 2013 (Cisco, 2009). The number of Internet users with access to mobile Internet also increases. In the Netherlands, for instance, the number of people with access to mobile Internet went up from 20% in 2007 to 30% in 2009. Similarly, the ability to access the Internet via a mobile phone increased from 8% of the total number of Internet users in 2007 to 15% in 2009 (Centraal Bureau voor de Statistiek, 2009). This trend is also mirrored on a worldwide level; AdMob (AdMob Mobile Metrics, 2010) reports that mobile traffic in each region increased at least four times in the last two years.

The increased influence of mobile devices on our daily lives leads to changes in human behaviour and cognition. In addition, this changed behaviour leads to new requirements for the technology. Castells et al. (2007) analysed the change in human behaviour caused by mobile devices, and speak of the *space of flows* and *timeless time* to describe this change. The space of flows refers to social interaction across multiple places made possible by mobile devices. As the networked mobile device makes communication possible virtually anywhere, the location of the person becomes less important. Related to that, timeless time refers to "the desequencing of social action", or a change of the boundaries between activities: multiple activities can overlap, can be worked at in the same time span, or are now independent of time, sequenced randomly. Both the space of flows and timeless time influence the behaviour of mobile device users in a way that (1) moments of time that were previously unused are now filled in by communication and consumption of information, and (2) travel patterns are influenced on-the-fly by mobile communication that allows appointments to be made (and changed) anytime. Moreover, mobile devices allow communication with peers irrespective of their location and time; people can be reached nearly anywhere and anytime. In turn, this means that people without mobile devices are more difficult to reach and can be left out of social activities. This digital divide will become even more apparent when young people, accustomed to the use of all sorts of technologies in their daily lives, bring their knowledge and innovative uses of technology to schools, the workplace, and society at large (Green & Hannon, 2007).

Summarising, mobile devices play an increasingly important role in society. The ubiquitous communication and information access made possible by mobile technology changes the way people interchange, consume, and create information. For example, information is accessed in different contexts and on the move, which typically results in short interactions with the information. These short interactions and the small screen factor of most mobile devices also influence the requirements on the information that is consumed; in general information is presented in short bits, to the point, and consists of visual multimedia like photographs, videos, augmented

with short pieces of text. In addition, most mobile devices can create audio, photographs, and video that provide users with new and easy ways of capturing real-world experiences for later access. The created information can be furthermore quickly shared with peers to augment social interaction. The new forms of communication and interaction with information have their reflection on personal, professional, and educational settings as well. Especially, if people can be reached anytime and anywhere and activities intermingle, the boundaries between private and professional time fade. Similarly, also the boundaries between formal and informal learning will fade as learners can use previously unused time to study, enrich their learning with activities encountered in real-life, and create their own learning contexts across places and independent of time. While mobile devices can provide new and unprecedented forms of learning support, the effects of this new technology on learning are still largely unknown. The large impact of mobile devices on society, the increasing need for up-to-date information in the knowledge economy, and the new opportunities mobile devices offer to address this need, make research into their use for learning support interesting if not essential. In this thesis, the use of mobile devices for lifelong learning support is therefore further investigated.

LIFELONG & TECHNOLOGY-ENHANCED LEARNING

In an economy where knowledge has become a product that is, at the least, as important as other economic assets, the production, management, and continuous development of this precious merchandise is in the centre of attention. While the use of knowledge management and knowledge engineering are important in keeping a competitive position, knowledge mainly resides with the knowledge workers that are part of the economy. In a rapidly changing knowledge economy, the workers need to constantly update their professional knowledge before it becomes outdated. The traditional divide between school and work where professional knowledge was learnt at school and applied on-the-job, is therefore fading. More and more, professional development is carried out during or after work, requiring the knowledge workers to keep up-to-date and study their entire career: the knowledge worker becomes a lifelong learner. Thus, in an effort to keep their economies competitive, governments recognise the need for and stress the importance of supporting their citizens in lifelong learning. For instance, the European Commission stressed the significance of lifelong learning for the European Union in a memorandum on lifelong learning (European Commission, 2000).

Koper and Tattersall (2004) describe lifelong learning as the actions individuals carry out during their lifetime to improve knowledge, skills, and competences according to a certain motive that can be personal, societal, or employment related. In addi-

tion, lifelong learning is portrayed as learning across multiple learning contexts that can be independent of time and place. As such, lifelong learning can entail a large variety of learning activities, ranging from institutionalised and highly structured formal learning on the one end, to opportunistic and unpredictable informal learning, on the other. Furthermore, learning can take place on a variety of places; ranging from formal institutions like schools and universities, to learning at the workplace, or learning for fun at home. Most importantly, lifelong learning is highly personalised and puts the learner in the centre; the lifelong learner is a *self-directed learner.* In self-directed learning a lot of emphasis is placed on meta-cognitive skills like organisation, planning, and reflection. In this respect, lifelong learning also emphasises the responsibility of the self-directed learner to create and structure the learning content himself (Koper & Tattersall, 2004). Additionally, a lot of lifelong learning is *social* and embedded in authentic learning contexts and communities of practice (Wenger & Lave, 1991); a heterogeneous community where experts and novices interact. Moreover, lifelong learning as the name says, spans across *longer periods of time*, can therefore be *less continuous*, and may *not be bound to specific periods in time*. Last, lifelong learning can be *situated*, i.e. it takes place on-the-job or in a real-world context that requires concrete, applied, and just-in-time knowledge.

The combination of different types of learning, long-term learning goals, and a multitude of learning contexts demand a good organisation and self-management of the lifelong learner: learners should plan their route towards completing their long-term learning goals carefully, estimate their competence level to find learning content appropriate to their current level of expertise, manage their previously completed learning activities in a way that they are accessible at any time, and find assistance from peers if necessary. Technology support for these activities would greatly simplify lifelong learning. To this cause, Koper and Tattersall (2004) present an integrated model for lifelong learning called a "Learning Network", which focuses on exploiting the strengths of a heterogeneous community of self-directed learners. A Learning Network integrates support for both formal and informal learning. On the one hand, Learning Networks provide technology support for self-directed learners, for example to help them assess their current competence levels (Kalz, Van Bruggen, Rusman, Giesbers, & Koper, 2007) or to plot-out paths to reach their learning goals (Drachsler, Hummel, & Koper, 2008). On the other hand, Learning Networks provide community-support for learners such as assisting learners to find appropriate peer support, raise social awareness, help in community reflection, or form ad-hoc communities to solve certain problems (Nadeem, Stoyanov, & Koper, 2009).

The possibility for a learner to carry a mobile device at all times makes the devices available in a variety of situations and contexts. In this sense, mobile devices offer unique opportunities to reach the learner anywhere and at anytime. Like mobile technology, lifelong learning is not specifically bound to a place or time. Sharples (2000) identified many similar characteristics in mobile technologies and lifelong learning. For example, mobile devices are often personal and user-centred, whereas lifelong learning is individualised and learner-centred. Similarly, mobile devices can be used ubiquitously and used in a variety of situations, and at the same time lifelong learning can also be situated and happen across several contexts. In addition, lifelong learning is collaborative, whilst mobile devices are a networked technology. Koper & Tattersall (2004) recognised the potential of mobile devices for lifelong learning as well, by arguing that mobile devices offer new opportunities "to create flexible, rich and interactive learning environments". Moreover, they specifically identify the potential of mobile information access for lifelong learning as being able to reach anyone, anywhere.

Furthermore, learning content can be accessed on-demand and just-in-time and could therefore be applied in the context it is normally used. In contrast, learning content could be adapted to the learner's current situation by accessing information about that situation from the mobile device' sensors. Thus, by using context-aware mobile technologies (Abowd, & Mynatt, 2000; Dey, Abowd, & Salber, 2001; Specht, 2007) various situated learning scenarios can be constructed, ranging from a passive information consumption to a more active creation of a personalised and contextualised learning context by the learner. Ogata and Yano (2004a) further specified the following positive characteristics of ubiquitous information access for learning: (1) the *permanency* of learning content, (2) the *accessibility* of learning content anywhere, (3) the *immediacy* of learning content access, (4) the *interactivity* with experts, teachers, and peers, and (5) *situating of instructional activities* or embedding learning in our daily lives*.* These characteristics of mobile technology offer interesting opportunities to support lifelong learning. In the following section we will address the problems in mobile support for lifelong learning that were addressed in this thesis.

PROBLEMS ADDRESSED IN THIS THESIS

The application of mobile technology to support lifelong and informal learning virtually anywhere and anytime requires the extension of existing software solutions for lifelong learning. Furthermore, the authentic real-world contexts that can be supported with mobile technology entail different forms of learning, external influences, and learner demands than learning in more formal contexts. Mobile support

for lifelong and informal learning therefore comes with a range of new problems that have to be investigated. The main problems we investigated in this thesis are the following:

1. *There is no agreed upon technical architecture for mobile lifelong learning support, nor is there a standard way of analysing, designing, and evaluating mobile social software for learning.* Such a technical architecture and the components it is comprised of should be designed, implemented, and evaluated. Mobile support for lifelong and informal learning requires a flexible technical architecture that can be easily extended and is grounded in educational theories. To come up with such a technical framework existing work in mobile learning has to be analysed. Furthermore, technical requirements have to be elicited and a possible integration with existing frameworks for lifelong learning has to be looked into. Last, the developed framework for mobile lifelong learning has to be evaluated in authentic real-world scenarios.

2. *Finding and investigating the relevant design options and parameters for just-in-time information filtering and presentation.* Lifelong and informal learning, in their broadest sense, take place everywhere, anytime and in a context or situation that is often not known beforehand. Also, they heavily depend on the learner's individual situation and for learning to be effective learning material should be tailored to the learner's current context. In addition, the interaction with mobile devices is typically short-lived and the amount of information that can be shown on them is limited. Therefore, the learning content presented to the learner should be the right amount at the right time. The form and most effective way of presenting learning content suitable for the learner have to be investigated.

3. *Understanding the effects of certain design factors on learning in authentic scenarios.* Learning in authentic scenarios is influenced by a number of factors, some of which are different from learning in more formal contexts. To investigate mobile lifelong learning support the factors that influence learning in authentic real-world scenarios have to be specified. Moreover, it has to become clear to what extent and how *these factors can influence learning.*

4. *Understanding the effects of embedding mobile-device-supported real-world activities in cross-context learning scenarios.* Traditional classroom settings have often been criticised on presenting knowledge out of the context it is normally applied in. Furthermore, learning in every-day life is taking place in many occasions, only some of them formal and focused on a clear learning goal with a specified outcome. Current research more and more stresses the role of supporting informal learning activities and integrating them with formal and life-

long learning approaches in Learning Networks (Koper, 2005). From our point of view, the role of continuous and ubiquitous support for learning activities in Learning Networks is essential to embed learning into every-day living, working, and learning and to support situated and informal learning in Learning Networks. However, learning activities that happen across locations and across time slots are difficult to manage and plan, and learning encountered in informal contexts is often not transferred to formal learning contexts. To increase the contribution of learning in informal learning contexts, the effects of real-world activities and cross-context learning support on learning have to be investigated more thoroughly.

OUTLINE OF THE THESIS

The thesis can be broken down in the theoretical foundations and an empirical part, addressing the different problems mentioned in the previous section. The structure of the thesis can then be laid out as follows. Chapter 2 to 5 provide the theoretical and technical foundations, while chapters 6, 7, and 8 describe three empirical studies carried out in mobile lifelong learning. Finally, chapter 9 concludes the thesis with a general discussion of our results.

Chapter 2 starts out to provide the theoretical foundations of the thesis by describing a review of the current state-of-the-art in mobile social software for learning. Trends and limitations of current approaches are identified and a reference model to classify the research is laid out. In chapter 3, the reference model is used to find a common ground between an existing approach for lifelong learning support, called Learning Networks, and current mobile social software for learning. Technical requirements for a mobile extension to Learning Networks were given, that were used as a basis for a technical framework portrayed in chapter 4. In addition, a concept implementation of the technical framework, called the ContextBlogger, is given in chapter 4. Last, chapter 5 illustrates two application scenarios in different domains that will be used as an inspiration for the empirical evaluations of the ContextBlogger software.

Three empirical evaluations were carried out as part of the research described in this thesis. Each evaluation evaluated mobile lifelong learning support from a different viewpoint, to address the main problems formulated in the thesis. Chapter 6 gives the first study that investigated mobile support for second language learning. The first study focuses on the comparison of different forms of learning content delivery, filtered dependent on the location of the learner or the object interacted with. Moreover, different forms of user interaction with the mobile clients were

considered. The study evaluated seven variations of a mobile client for language learning with 35 adult learners. The second study, given in chapter 7, was carried out in the building engineering domain. Chapter 7 evaluated a mobile client and a web portal supporting learners in a cross-context scenario that involved a fieldtrip. Two groups of university students, a total of 18, were compared on their performance on a compulsory assignment: one group went on a mobile-device supported fieldtrip, while the other group had to rely on information found in digital and non-digital resources. The second study evaluated the difference between both groups in general, and the effect of mobile content creation and annotation in the real world in specific. Last, chapter 8 describes our third study, which looked into mobile support of second language learners as well. The third study explored the use of learning content delivery and organisation on mobile devices. Moreover, two types of authentic tasks are compared on their effect on learning behaviour and performance. In addition, two types of information organisation on the basis of the learner interaction with the learning content were examined. The study was carried out with 44 secondary school students.

In chapter 9, the general discussion, we review the research in this thesis and its findings. After that, the practical implications for the research in mobile lifelong learning are looked into. In addition, the extent to which the results can be generalised is described. Last, we conclude with a number of suggestions for future research.

CHAPTER 2
A Reference Model for Mobile Social Software for Learning

ABSTRACT

This chapter provides a reference model for mobile social software and uses it to analyse the current state-of-the-art in its applications for learning. A general overview of the literature in the field and the available projects will be given. The reference model for mobile social software helps us to (1) find out to what extent mobile social software for learning has already been used until date, (2) identify gaps and limitations in current research and provide new ideas and innovative approaches for learning based on these gaps, and (3) position our current research work in preparation of a study of applications of mobile social software for learning. After that, the limitations of the current state-of-the-art and suggestions for future research are briefly described. The last section provides the conclusions of this chapter.

INTRODUCTION AND BACKGROUND

The recent uptake of mobile devices has made access to personal social networks available nearly anywhere, anytime and anyplace (Castells et al., 2007; Rheingold, 2002). Mobile messaging can be considered as one of the first 'killer applications' for mobile devices that has already been introduced several years ago. Different studies have demonstrated the new possibilities of messaging and their potential for learning support as for inclusion, engagement and mobile support (Mitchell, Race, McCaffery, Bryson, Cai, 2006; Riordan & Traxler, 2005). In recent studies, the impact of this new technology on communication and learning in the younger generation is described as highly relevant for new forms of learning support (Green & Hannon, 2007). With the introduction of new multi-faceted mobile devices, the latest research aims at the potential of mobile content creation and sharing, personalised and contextualised services or sense-based and contextualised human–computer interaction. Additionally, with the current trends in social software and new types of contextualised mobile technology like presence sharing, contextualised messaging (www.jaiku.com), or sensor data sharing (http://www.apple.com /de/ipod/nike/run.html), technology is coming to end users from which the authors expect to have great potential for everyday learning support.

Social software has its roots in research on Groupware and Computer-Supported Cooperative Work (Cockburn & Thimbleby, 1991; Greif, & Sarin, 1986). Anderson (2005) states that social software has several applications and characteristics that can prove useful for learning support: presence tools, notification, filtering, cooperative learning support, referring, student modelling, introducing learners to each other, helping others and finally documenting and sharing constructed objects.

Especially, educational blogs have recently become a popular way of collecting personal information and learning experiences (Oravec, 2002) and combine this with reflection in a community. Mobile blogging as a mobile application for blogging provides an instant way of accessing and collecting personal memories. Mobile blogging applications for personal reflection or community building have been researched in research projects in undergraduate and higher education (RAMBLE Project, 2006; Specht & Kravcik, 2006).

In context-aware computing, a variety of notions of context has been discussed and automatic possibilities for context detection, context matching, and sensors and tagging for context have been researched (Abowd & Mynatt, 2000; Dey & Abowd, 2001). Context-aware computing together with ubiquitous and pervasive techniques can result in systems that adapt to user's identity, preferences, location, environment and time (Gross & Specht, 2001; Specht & Kravcik, 2006; Zimmermann, Lorenz, & Specht, 2005). For identifying and tagging in context-aware systems, a variety of new technologies is currently developed. Classical tagging approaches for objects found in, for example, early museum-guiding applications (Oppermann & Specht, 2000) are nowadays again a hot topic with technologies, such as radio frequency identification (RFID) tagging, that are already available or built into mobile devices.

In that sense mobile social software allows for the contextualisation to the individual's social and physical environment and enables new forms of learning support, including: ubiquitous multimodal notification, ubiquitous multimodal messaging, ubiquitous content exchange and sharing, contextualisation services or physical world tagging. Furthermore, lifelong learning approaches in Learning Networks (Koper, 2005), which investigate the support of informal learning activities and the integration with formal learning, may benefit from these new kinds of technologies and their possibilities for embedding learning experiences in everyday life.

The strengths of embedding learning support in authentic learning contexts have been argued for quite some time in the educational literature (Wenger & Lave, 1991). Combining the strengths of both mobile and context-aware systems and applying them to educational systems can lead to contextualised learning support by utilising information about the learner's environment and adapting the learning content to that information, as described in Zimmermann et al. (2005). From a pedagogical point of view, the concepts of reflection in action and reflection about action (Schön, 1983, 1987; Wenger & Lave, 1991, Zimmermann et al., 2005), and embedding learning support into communities of practice are the basis of new approaches in mobile and social learning software (Bo, 2002; Specht & Kravcik, 2006).

Recent studies on mobile learning have shown that already a variety of best practices and approaches for using mobile devices to support learners is being applied, nevertheless most of them are proprietary solutions lacking a sound pedagogical approach and conceptualisation and also an open and flexible underlying infrastructure (Naismith, Lonsdale, Vavoula, & Sharples, 2004; Tatar et al., 2003). In addition to that, several challenges for collaborative infrastructures for collaborative work environments are presented in (Laso-Ballesteros, 2006). Among the challenges identified are: activity-oriented context-aware collaboration features provided by the collaborative infrastructure supporting human interactions, pervasive collaboration support and heterogeneous devices with embedded collaboration capabilities. Context-aware mobile devices providing communication and collaboration features could provide a solution for these challenges (Lundin, & Magnusson, 2002).

MOBILE SOCIAL LEARNING IN CONTEXT

Recently, Sharples et al. (2007) in their theory of mobile learning stressed the importance of conversations for learning. Conversations, they argue, are a key element for constructing knowledge in collaborative tasks. Related to that, Wenger and Lave (1991) have stressed the importance of collaborative learning and embedding the learner in communities of practice. With the increasing mobility of people and the possibilities of ubiquitous information access, the role of mobile devices in supporting learning also increases. Moreover, mobile access to online learning communities and social networks would simplify user participation in and awareness about learning processes in a community.

Additionally, still most social interactions take place in a real-world context and the application of mobile devices supporting these interactions would provide opportunities for an increasingly efficient community building, for example, turning an accidental encounter into a learning moment. Already, social software in online environments tries to employ the power of communities for more efficient or more knowledgeable information processing. In that sense, Anderson (2005) has also emphasised the importance of social software for learning. Additionally, Knight (2005) highlights the importance of situated learning support by defining learning as a social practice in which learners develop their identity through participation in specific communities and practices. Mobile social software offers a learner the opportunity to become part of a learning community and at the same time enables learning in authentic contexts. From the author's point of view, mobile social software applications combine virtual and real-world support for social interactions and collaboration in a real-world context.

The importance of mobile social software for learning has also been supported by recent research in a review of mobile technologies for learning. Nesta FutureLabs (Naismith et al., 2004) described the underpinning of current mobile learning approaches by common learning paradigms. Moreover, in Stead (2005) findings are presented that learning works best for a learner and tutor if the mobile devices are combined with group activities or other media. Additionally, learners themselves seem to be enthusiastic about using the mobile devices for collaboration and communication. For example, Smordal, Gregory, and Langseth (2002) found out that students were using the mobile devices as a communication tool. The project concluded that the mobile devices used should be seen as 'potential gateways in complicated webs of interdependent technical and social networks'.

To support this opinion about the importance of mobile social software for learning, a review of the current state-of-the-art in the field will be presented in this paper. As a basis for this review, the next section will present a classification of mobile social software for learning for a number of reasons. Firstly, during classification a reference model is derived that also can be used as a basis for future application of mobile social software in the context of learning. Secondly, the classification should help to find out to what extent social software for mobile learning has already been used to this date. Thirdly, a categorisation helps us to identify gaps in current mobile social software research and provide ideas for new community-based mobile learning software based on these gaps. Fourthly, by considering mobile social software in general, we hope to find mobile social software that can be applied in innovative approaches for learning. Finally, the state-of-the-art presented here will help us to position our current research work in preparation of several empirical studies and development of mobile social software for learning.

A CLASSIFICATION OF MOBILE SOCIAL SOFTWARE FOR LEARNING

As the research in mobile social software has a background in context aware and ubiquitous computing as well as mobile learning research and social software, the authors have considered different classification schemes from those backgrounds. Basically in our classification we apply the following: content, context, purpose, information flow and pedagogical model. The classification was applied on the literature, which mostly consisted of the papers of two major conferences in the field of mobile learning since the year 2002: MLEARN and WMTE.

Content – describes applications based on the artefacts exchanged and shared by users

A framework for analysing the features of mobile learning as well as mobile learning systems is given in Sharples et al. (2007), where the authors distinguish between a semiotic layer, for analysing mobile learning from the learner's viewpoint, and a technology layer for describing mobile learning from a technology perspective. For both layers, the framework describes the same concepts: mediating artefacts, subject, object, control, context and communication; the specific meaning of a concept, however, depends on the selected layer. For example, the control dimension can describe either human–computer interaction or social rules for technology or semiotic layers, respectively. Furthermore, in the learning process the learner uses mediating artefacts and objects. First, to analyse the mediating artefacts from a technological perspective, the classification needs to analyse the mobile learning technology used, more specifically to analyse the *kind ubiquitous and pervasive system*. The semiotic perspective identifies the learning resources, the object and environment in which the learning is carried out. In our analysis of the literature, the learning resources we mainly found were annotations, documents, messages, and notifications.

The MOBILearn project (Bo, 2002) combines multimedia content creation, content delivery and stores context metadata about that content. Interestingly, the KLIV project (Brandt, Björgvinsson, Hillgren, Bergqvist, & Emilson, 2002; Brandt, Hillgren, & Björgvinsson, 2003) delivered video content to Personal Digital Assistants (PDAs) used by nurses and demonstrated the importance of the fact that the content was created by the same user community even if the creation and the usage of content were strictly separated. Another system that provides functionality for content delivery is xTask (Ketamo, 2002). xTask adds the collaborative editing of content and instant messaging for discussing the content to foster more dynamic content production in collaborative distributed settings. Environmental Detectives (Klopfer, Squire, & Jenkins, 2002) is an example that along with content creation stores location metadata for the content created; students take pictures in an outside setting to enhance the learning experience in remote participation. A similar approach was taken in the RAFT project, which demonstrated effects on classroom engagement and participation with the integration of authentic learning materials from remote fieldtrips (Bergin et al., 2007).

Mobile social software for content creation often also allows for making annotations. A specific example is C-notes (Milrad, Perez, Hoppe, 2002), a solution for users to create textual notes to annotate classroom presentations. The notes are created using a PDA or a special pen to scan text and are stored in a group archive for later access or exchange with other users. Along with each note some metadata

such as author, date and keywords can be stored. PhotoStudy (Joseph, Binsted, Suthers, 2005) annotates content with images or audio recorded on mobile devices. Likewise, mobile Collaborative Learning Tool (mCLT; Arrigo, Gentile, Taibi, Chiappone, Tegolo, 2004) is also aimed at note taking, but adds e-mail or SMS communication to enable users to instantly create and share live data and annotations. A slightly different approach is presented in Jansen, Rossmanith, Uzun, and Hoppe (2005) that delivers content on a public display board called SynchroBoard; most of the information on the board is public information, but is adapted to individual users based on Bluetooth information from their mobile phones. This enables personal perspectives on public content objects.

Among the mobile social software considered a range of communication tools are found, providing several different communication channels. For instance, the HandLeR project by Sharples, Corlett, Westmancott. (2002) supports direct voice communication, whereas Silander et al. (2004) provide text-based communication via an instant messaging tool. Conversely, the Musex system (Yatani, Sugimoto, Kusunoki, 2004) does not provide the means of communication itself but focuses on enkindling face-to-face discussion. It does this by using paired PDAs to inform two coupled learners about the correctness of their answers to a certain question.

The WELCOME mobile client, described in Berger et al. (2003), sends SMS notifications to university students whenever new material or new postings have been added to the university's e-Learning system. Furthermore, invitations to private learning groups are also sent by SMS notification. Likewise, Silander et al. (2004) present a system that sends notifications about whether or not content has been added to a shared knowledge map. Liu and Kao (2005) describe the use of SMS messages to inform students about the collaborative activities of their peers. In most systems, notifications are used to notify either about nearby people with matching interests (Eagle & Pentland, 2005) or someone about the current activity of other persons.

Context – describes applications based on the context parameters taken into account for learning support

The context dimension describes *the kind of contextual information* that is used in the system; contextual information can be used to describe or derive information about the user (describing, for example, the learner's personal preferences), information about the environment (describing the learner's physical environment), or information about the social context of the learner (describing the social relationships a learner is involved in and the social networks the learner is part of). In community systems, the context describes where a user is located within the commu-

nity (boundary, centre) and the number and kind of relations this user has with other users within the community. In context-aware computing, a variety of notions and interpretations have developed over the years. Zimmermann et al. distinguish between definitions by synonym or definitions by example which mainly name and describe certain context parameters as location, identity, time, temperature, noise, as well as beliefs, desires, and commitments and intentions (Zimmermann, Lorenz, & Oppermann, 2007). Furthermore, they introduce an operational definition of context describing the following main categories of the context information:

- Individuality context includes information about objects and users in the real world as well as information about groups and the attributes or properties the members have in common.
- Time context, basically this dimension ranges from simple points in time to ranges, intervals, and a complete history of entities.
- Locations context is divided into quantitative and qualitative location models, which allow to work with absolute and relative positions.
- Activity context reflects the entities goals, tasks and actions.
- Relations context captures the relation an entity has established to other entities, and describes social, functional and compositional relationships.

In our analysis, several possible types of context filters were identified including identity/individuality, time, location, environment/activity and social/relations context. Eagle and Pentland (2005) describe a system that sends notifications based on identity information in user profiles and proximity information derived from a mobile phone's Bluetooth transmitter. The notifications are used to increase serendipity in social relationships and to inform users about nearby users with similar interests.

Identity context is often also combined with other forms of context. One specific example of such a combination is given by Ogata and Yano (2004b) who present 'Collaborative Learning support system with a Ubiquitous Environment' (CLUE), a system for learning English in real-world situations. CLUE uses (1) a learner profile to adapt the learning content to the learner's interest and (2) location information to link objects/locations to suitable English expressions, i.e. appropriate learning content. Likewise, MOBILEARN combines a user profile and user position, to facilitate personalised and location-based information delivery (Bo, G., 2002). AwarePhone (Bardram & Hansen, 2004) uses several context-parameters at the same time. First of all, location is used to locate fellow employees within the hospital. Second, a calendar artefact is used to capture and share time context and also indicates the activity of a user at a certain moment. The activity is furthermore given by a shared status message. The combination of these three context parameters leads to what the authors call 'context-mediated social awareness'.

Environmental context information is used in several systems, most notably Query-Lens (Konomi, 2002), which focuses on information sharing using smart objects. Moreover, the Tag Added learNinG Objects (TANGO) system (Ogata & Yano, 2004a) and the Musex system (Yatani, Sugimoto, & Kusunoki, 2004) detect objects in the vicinity by using RFID tags. Moop (Mattila, & Fordel, 2005) couples a Global Positioning System (GPS) location to observations/information gathered in the field for later analysis in the classroom. Wallop (Farnham, Kelly, Portnoy, & Schwartz, 2004) allows its users to discover social relationships and provides social awareness by storing and analysing social context information; to derive the social context communication patterns, system interactions and co-occurrence information were analysed.

Purpose – describes applications according to the goals and methods of the system for enabling learning

Richter and Koch (2007) define three main purposes of social software: identity management, information sharing and relationship management. Hence, social software applications can be described according to their focus on information management (Wikis, Blogs), identity management (Weblogs, Portfolio Systems), and relationship management (Networking Platforms, IM Applications). In combination with learning, Anderson (2005) identifies several different purposes for social software: presence tools, notification, filtering, cooperative learning support, referring, student modelling, introducing learners to each other, helping others, and finally documenting and sharing constructed objects.

A main purpose found in social software systems for learning support is *sharing content and knowledge* among a community of users. Interactive Logbook, presented in Bull et al. (2004) and Chan, Corlett, Sharples, Ting, and Westmancott (2005), is a shared workspace system supporting mobile learning with mobile access to documents and handwritten editing of content. A variety of learning management systems extend their basic functionality with services and software for mobile access (Bo, 2002; Houser, & Thornton, 2005; Vavoula & Sharples, 2002). Besides the sharing of content, some approaches also provide facilities for the collaborative annotation of content and note-taking, where personal messages can be attached to the learning content to facilitate personal or community reflection, as for example in C-notes (Milrad, Perez, & Hoppe, 2002).

One of the most popular classroom scenarios is a mobile social tool that *facilitates discussion and brainstorming*. Mobile notes (Bollen, Juarez, Westermann, & Hoppe, 2006) facilitates brainstorming and discussion via different kinds of annotations and voting. Ng'ambi (2005) presents a shared knowledge approach called DFAQ – a

mobile social system for Dynamic Frequently Asked Questions. Yet another kind of solution aims at collaborative concept mapping, for instance PerkamII – a knowledge awareness map for sharing knowledge, collaborating and sharing individual experiences (El-Bishouty, Ogata, & Yano, 2006). PerkamII and QueryLens (Konomi, 2002) additionally use real-world objects tagged with RFID to interact with real-world contexts. Mobile recommender systems like MovieLens Unplugged (Miller, Albert, Lam, Konstan, & Riedl, 2003) give access to community-generated metadata about movies, enable instant connection to real-world objects, and develop a community rating and review of the described movies.

Another group of systems mainly aims at *social awareness*. Several different types of awareness can be identified. Nova, Girardin, and Dillenbourg (2005) have researched the impact of location awareness on collaborative task performance. Another example for a technical solution of location-based campus support has been given in (Ferscha, Beer, Narzt, 2001). A related but more extensive system is presented in Eagle and Pentland (2005), which combines location and interest-based awareness, and should increase serendipity. In this example, location is coupled to a similarity in user profiles to notify people when someone with similar interests is nearby. Messeguer, Navarro, and Reyes (2006) describe a system that uses location information in a classroom for group awareness and identification group structure. Conversely, Kajita and Mase (2006) bring forward a classroom system that makes the teacher aware of current problems and progress of students. Furthermore, Bardram and Hansen (2004) describe AwarePhone, a system for activity awareness in a hospital. AwarePhone displays the current activity of a doctor and can be used by nurses to find out an appropriate moment to interrupt him or her.

Another purpose is to *guide communication* and provide a central place for it. An example is given by Farnham et al. (2004) with their Wallop system designed for maintaining and extending of a user's social network; it provides a central place for people to contact each other. Additionally, most of these communication systems try to bridge the gap between geographically dispersed people to include them in collaborative processes. Raymond et al. (2005) present a synchronous communication application (instant messaging, audio and video conferencing) that also provides collaboration facilities like a white board. Similarly, the HandLeR project (Sharples, Corlett, & Westmancott, 2002) offers conversation between mobile learners to support knowledge sharing between them and teachers, experts and peers.

Mobile collaborative games are good examples of enhanced *engagement and immersion* of users and learners by embedding them in real-world contexts. In education, games are mostly used to motivate students and to increase their participation (Mitchell & Savill-Smith, 2004). Locatory is a mobile multi-user game (Unger,

2005; Zielke, 2005), which implements a ubiquitous version of a memory game in which two competing teams, each consisting of two collaborating people, should find the tiles corresponding to each other and which are spread throughout an office environment. In Human Pacman (Cheok et al., 2004), the participants play the characters of several pacmen and ghosts, and have to collaborate to obtain virtual cookies or capture pacmen, respectively. Environmental Detectives (Klopfer, Squire, & Jenkins, 2002) is an example of an educational game that enables groups of students to investigate a simulated pollution scenario by combining real-world and virtual data.

Information flow – classifies applications according to the number of entities in the systems information flow

The information flow between users and other entities within a social software system is described by several parameters. Johansen (1988) portrays a groupware software typology that makes a distinction between two values of place (same, different) and time (same, different). By combining different values of place and time, different ways of interacting and hence different kinds of systems can be analysed. When, for instance, both place and time are the same, a face-to-face meeting as a way of interaction suffices. However, the interaction between people is synchronous and distributed when they meet at the same time, but are not located at the same place; an interaction pattern that, for example, appears in videoconferences. Earlier in the paper the contextual parameters of individuality, locations, time, environment/activity and relations context were mentioned. The influences of place and time can be perfectly modelled by using at least two of these contextual parameters, location and time, and therefore will not be considered here.

Another aspect governing the information flow is the relationships between users and other entities in the system. The relationships can be described using a ratio relating the number of users or entities on either side. The ratio identifies the number of relationships possible. The following values are identified for the ratio describing the information flow: one-to-one, one-to-many, many-to-one, and many-to-many.

An example of a one-to-one flow of information is the system in Liu and Kao (2005) that uses shared displays in a classroom to support collaborative learning. Also the social awareness systems that rely on serendipity to introduce familiar strangers to each other provide a one-to-one communication.

The information flow in classroom response systems, as for example Chen et al. (2005), is often many-to-one; the students in the classroom communicate with the

teacher. However, classroom response systems provide the teacher with an aware-ness of problems students have and therefore are also aimed at providing better one-to-one relationships. For direct one-to-one communication in a classroom technical support is often not needed because it is mostly face-to-face. Related to a classroom response system is 'Ask the Author' (Deng et al., 2005) a conference system that supports people in a conference audience asking the author questions. The mobile system only provides a many-to-one information flow by allowing the audience to post questions to the author via their mobile devices; the author then can answer the question face-to-face, providing a one-to-many information flow.

Some systems integrate multiple information flows. C-Notes (Milrad, Perez, & Hoppe, 2002), for example, integrates many-to-one (students to teacher), one-to-many (student adds interesting articles and notes to the system, readable for others as well) and many-to-many (content can be added by more students and viewed by more).

Pedagogical paradigms and instructional models

Naismith et al. (2004) in their review of mobile learning identified several theory-based categories of activity that are relevant for the design of mobile learning: be-haviourist, constructivist, situated, collaborative, informal and lifelong, and learning and teaching support. Mainly in the classification, we will focus on the different pedagogical paradigms of behaviourist, cognitive, constructivist, and social con-structivist approaches found in the literature. Collaborative learning support, how-ever, is used throughout all mobile social software for learning, considered in this review. Therefore, this subsection analyses the other pedagogical models that have been applied in combination with the collaborative one.

Behaviourist approaches on learning are the foundation of most notification sys-tems. Notification systems often want the learner to respond in a certain way ac-cording to the notification. The stimulus of the notification leads to attention to a certain event in the learning process. For example, in Eagle and Pentland (2005) notifications are used to introduce people with similar interests to each other to highlight a learning opportunity. Moreover, the more standard form of notification systems (Berger et al., 2003; Liu et al., 2005; Silander, Sutinen, & Tarhio, 2004) wants the user to react on or learn about some peer activity being performed.

Constructivist approaches like MediaBoard (Colley & Stead, 2004) create a mobile accessible working space aimed at fostering interaction in a community of practice (Wenger & Lave, 1991). Annotation tools like Mobile Notes (Bollen, Juarez,

Westermann, & Hoppe, 2006) used in brainstorming sessions are often also designed from a constructivist point of view.

An example of situated learning support is the RAFT project that aims 'to provide a cooperative learning environment spanning fieldtrip and the classroom' (Hine, Rentoul, Specht, 2003). Likewise, Silander et al. (2004) combine situated learning in the form of a fieldtrip with students available in a classroom. Similarly, Mattila and Fordel (2005) and Paredes et al. (2005) also discuss a system aimed at fieldtrips combined with a classroom discussion about the results of the fieldtrip afterwards.

Informal and lifelong learning approaches are encountered in some systems. QueryLens (Konomi, 2002) is an example of such a system, in which a community of interest develops around real-world content, in this case music. Another platform specifically aiming at lifelong learning support is KLeOS (Vavoula & Sharples, 2002) allowing users to structure their learning activities, resources and knowledge to support learning anything, anywhere, anytime.

Most examples of learning and teaching support considered in this review are to a large extent applied to formal learning. Chen et al. (2005) present a classroom response system that allows students to respond to questions asked by the teacher. Saito, Ogata, Paredes, Yano, and San Martin (2005) assist teachers in basic administrative tasks, like monitoring students' attendance, but also fosters collaboration between students.

A REFERENCE MODEL FOR MOBILE SOCIAL SOFTWARE FOR LEARNING

The previous subsection identified the dimensions of a reference model for mobile social software for learning. Moreover, for each dimension a range of possible values has been identified. The reference model has been used to classify already existing applications of mobile social software for learning. However, it can also be used as a basis for future applications. For example: an already existing social software system can be analysed and extended to a context-aware one, using this model. An overview of the reference model for mobile social software has been shown in table 2.1, which combines each of the identified dimensions with its possible values.

Table 2.1
A reference model for mobile social software for learning

Dimension				
Content	Context	Information flow	Pedagogical model	Purpose
• Documents	• Individuality Context	• One-to-one	• Behaviourist	• Sharing
• Annotations	• Time Context	• One-to-many	• Cognitive	• Content and Knowledge
• Messages	• Locations Context	• Many-to-one	• Constructivist	• Facilitate Discussion and Brainstorming
• Notifications	• Environment or Activity Context	• Many-to-many	• Social Constructivist	• Social Awareness
	• Relations context			• Guide Communication
				• Engagement and Immersion

Figure 2.1 shows a graphical representation of the reference model that gives an overview of how all concepts in the reference model are related. This is illustrated with an example application of a location-based document sharing. In the artefact layer, the different content considered is shown for the example application a user connects a physical object (1) with a document (2) and defines the connecting context (1). Furthermore, he specifies a location trigger for notifying other users (3) when they interact with the physical object.
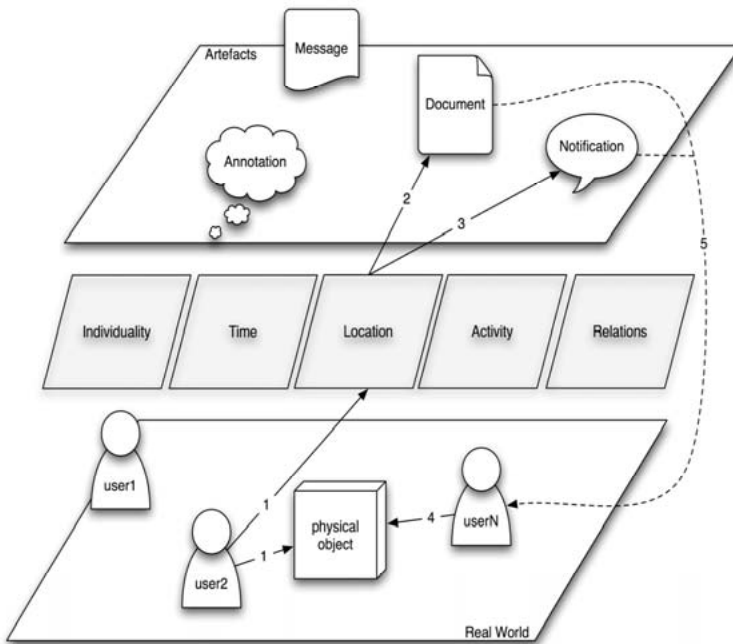

Figure 2.1: A graphical representation of a reference model for mobile social software for learning

If other users interact with the object, notifications (4) and a document sharing process will be triggered (4). The reference model includes all necessary means to describe the content, context, and relationships included, and also gives a framework for the instructional models based on different pedagogical paradigms.

SUMMARY: TRENDS IN CURRENT STATE-OF-THE-ART

In the preceding sections, the current state-of-the-art for each dimension of the reference model was described. In this section, a summary of the trends for each dimension will be given as a basis for the analysis of the limitations in the next section.

The wide range of systems aimed at sharing content and knowledge has its impact on the dimension that considered the types of content available in mobile social software. Most of the mobile social software supports some kind of content sharing. Two categories of systems using content can be distinguished. The first are systems in which the sharing of some kind of multimedia information is the main focus of attention. Conversely, the second are systems, which annotate some other content or are aimed at creating notes; the notes are not the main focus of the learner but rather are used to support learning by organising the learning process. Communication features offered by current mobile social software range from direct voice communication, instant messaging to leaving some kind of text message on a shared space. Communication technology is not the main consideration of a lot of research, but is rather seen as an extension to other systems. The main reason would be that the most popular devices, mobile phones, already offer outstanding communication capabilities. Surprisingly, the use of metadata and notifications was also not found extensively. Content metadata, specifying some extra information about the content stored, has been found in some cases. Most metadata found, however, specified a particular context; most often metadata used to describe location context was found. Notifications were mostly encountered in the form of SMS-messages that were sent about a change in a shared context: someone in the group edited shared content or a person was added to the user's community. On the contrary, personalised messages focusing on making the user aware about interesting content in his vicinity were not found very often.

The second dimension analysed was the kind of context filter used. The most widely applied form of context filters was a location filter that adapts the learning content to the user location. Also social context information has been put to use in the social awareness systems more than the remaining context parameters; social context

is for example used to derive relationships between people. There are a number of systems providing personalisation through identity context, a system using calendar information (time context) and some using environment context in the form of tagged real-world objects. Unfortunately, most of the other context parameters have not been commonly applied. In that sense, especially, the software systems that use simpler context parameters like location and time and use them to derive more complex context information, for example social awareness information, are in our opinion most interesting.

The third dimension considered was the purpose of the system. In the mobile social software research considered throughout the review, the systems aimed at sharing content and knowledge were mostly encountered. The content and knowledge sharing systems were closely followed by *social awareness* systems, which judging from the references have become more popular in the last years. Functionality that guides communication often has been combined with other system functionalities and rarely seems the major aim of a system. However, especially social awareness systems focus on improving or enkindling face-to-face conversations, which is the implicit aim of a lot of mobile social software we have analysed. Mobile collaborative games, specifically aimed at learning, were not encountered that much.

The cardinality of the information flows in mobile social software was given by the fourth dimension. The one-to-one collaborative systems found were either intended for peer-feedback, or for bringing people into contact with each other; social awareness. Moreover, the direct communication flows possible in some systems are often one-to-one. Many-to-one or one-to-many relations are often seen in formal learning scenarios. Classroom response systems, for instance, are many-to-one; the students can respond to their teacher. More informal approaches, for example shared content repositories, often integrate several information and communication flows.

Fifth and the last, the pedagogical model used as a basis for the system was considered. Previously, the great availability of learning solutions aiming at content was already discussed. Most of these systems are based on a constructivist pedagogy, which is therefore also widely available throughout mobile social software for learning. Next to constructivist pedagogies, situated pedagogies are more widely encountered in the research considered, especially in the software systems that use a form of adaptation to the location of the user. Systems for learner and teacher support are also widely available, but with a focus on formal learning in the classroom. Finally, the behaviourist and informal and lifelong pedagogies are less available.

The summary of the current state-of-the-art presented in this section already hints at possible limitations in mobile social software for learning. The next section will describe the limitations more clearly, as a basis for suggested improvements for current learning solutions.

LIMITATIONS OF CURRENT SOLUTIONS

During the review and classification of the software, there were already some limitations of the current solutions implicitly identified. An overview of the limitations we think are most important is given in this section, for each dimension of the reference model.

First of all, some limitations of the content dimension are identified. While a lot of the systems aimed at sharing various forms of multimedia documents were encountered, the use of metadata about those documents is not that widely found; most of the metadata stored relates to author information or location data about content. One possible explanation for this absence of metadata could be the large overhead of implementing a metadata storage and query system; especially this is true for the small systems that were mostly encountered in this review. Furthermore, the support for ubiquitous notifications is not widely available, and mostly relates to some collaborative action performed by the learner's peers. Notification based on contextual information to minimise interruption has not been found during this review.

Second is the usage of context filters. Mobile social software for learning rarely uses other context information besides location and identity context. For ubiquitous learning support, the time, the environment of the learner and especially the activity a learner performs are important. Therefore, time, environment and activity context should be more considered in future research. Moreover, a combination of context parameters to derive more complex information about the learning situation has not been largely encountered.

Third, relating to the purpose dimension we feel that there is a lack of integrated solutions available. A system that provides content creation and delivery combined with social awareness systems for effective community building was not found in the literature considered.

Last, the pedagogical models that have been used mostly focus on constructivist and situated learning. In our opinion informal and lifelong pedagogies should be given more attention, especially since these are the forms of learning that take place anywhere, anyplace, anytime, i.e. mobile or ubiquitous learning.

SUGGESTED EXTENSIONS FOR IMPROVED LEARNING

Based on the limitations identified in the previous section, suggested extensions for mobile social software for learning will be given in this section.

To begin with, a better and wider use of metadata information throughout the systems is suggested. The storage of metadata information makes it easier to find appropriate content for appropriate learning activities. For example, content stored along with context metadata in a specific learning episode can later be reused and found in similar learning situations. An evaluation of the efficiency of such approaches can be found in the literature on recommender and tutoring systems based on episodic memory approaches (Weber & Specht, 1997).

Also, notifications should be more widely used and tailored to a specific learning situation, above all not interrupting that situation by drawing most of the learner's attention to the notification itself. The kind of notification (Eagle & Pentland, 2005) provided is particularly interesting because it integrates a notification with proximity information and information from a personal interest profile. However, next to this integrated approach, we did not find further examples where for instance time context, relationship contexts and more parameters were combined to further filter notifications. Moreover, notifications could also be extended to draw attention to interesting places or current events in the vicinity of a mobile learner, based on a personal profile and located calendar information.

Likewise, a better and wider use of more complex context information is suggested. Particularly, the time and environment/activity context deserves more attention in our opinion. The environment and activity context is the subject of ubiquitous computing research (Abowd & Mynatt, 2000; Weiser, 1991), and in this sense mainly two aspects are interesting: first, attaching content to real-world objects and using these enriched objects as new shared content repositories capable of building new learning communities. Second, the use of ubiquitous software systems and context information to try to support the current activity of the learner.

Moreover, we suggest the implementation of systems integrating a range of social software functionalities. Especially, the combination of shared content repositories with a form of social distributed awareness could be used to build more active and aware learning communities.

Last, in our opinion more attention should be given to support informal and lifelong learning by using mobile social software approaches. Informal and lifelong learning is a learning that takes place anywhere, anyplace, anytime, and especially this kind

of learning could benefit from mobile social software applications embedding the user in one or more communities of practice wherever and whenever. Especially, the integration of informal and formal learning approaches should be investigated, in the sense of lifelong learning that incorporates formal education with learning encountered in everyday life. We feel this integration can be already, to some extent, made possible by combining content injection, content delivery and social awareness (by notifications).

Summarising the following extensions to the current state-of-the-art are brought forward:

- provide more integrated systems with a range of functionality
- better and wider use of metadata
- more advanced and wider use of notification techniques
- an improved adaptation to the user's personal preferences and learning environment or situation by using more kinds of context information than location and identity alone, and use of techniques to derive more detailed or higher level context information by a combination of different context parameters
- more attention to systems aiming at informal and lifelong learning.

CONCLUSION

In this paper, a reference model for mobile social software for learning was described. The reference model consisted of five dimensions, being: purpose, content, context filter, information flow and pedagogical model. Current research was classified according to the reference model. The results of the classification suggest that most of the mobile social software for learning aim at providing a shared content or knowledge repository and provided storage for all kinds of multimedia information. Additionally, location and identity context were used most, and constructivist and situated pedagogic models form the foundation of most current software solutions. Based on the limitations of the current state-of-the-art in mobile social software the following improvements were suggested: creating integrated systems to address a range of different learning purposes, extending the use of metadata, improved use of notifications, and more use of context information, as well as the combination of several context parameters to derive more detailed information about a learner's current situation. Moreover, we hope to see more focus on systems for informal and lifelong learning.

CHAPTER 3

Educational and Technical Requirements for a Contextualised Multi-Platform Learning Framework

ABSTRACT

This chapter describes a multi-platform extension of Learning Networks. In addition to web- and desktop-based access, we propose to provide mobile, contextualised learning content delivery and creation. The extension to a multi-platform extension is portrayed as follows. First, we give a description of Learning Networks, the kind of learning focused on, and the mechanisms that are used for learner support. After that, we illustrate a possible extension to contextualised, more authentic forms of learning mediated by mobile devices. Moreover, we elicit requirements for a multi-platform Learning Network system.

INTRODUCTION

Lifelong learning takes place anytime and anyplace. Next to formal learning scenarios in a classroom, a great deal of learning is informal, happening in unforeseen places and at unexpected times. Recent developments in mobile technologies increasingly make it possible to support learning on the move and make use of these spontaneous learning situations. Moreover, mobile technology offers new chances to integrate spontaneous learning in a more formal learning scenario. Already, we see a tendency to use blended learning scenarios combining different forms of learning, and integrating various ways of content access; for instance, web-based, desktop, and mobile. A couple of mobile projects aim at a better integration of mobile learning scenarios into more formal, classroom-based scenarios. MyArtSpace (Sharples, Lonsdale, Meek, Rudman, & Vavoula, 2007), for example, strives for an easier combination of a museum trip with lessons before and after the visit. Similarly, the RAFT project (Terrenghi, Specht, & Stefaner, 2004) endeavoured to improve the benefit of museum visits by mediating the communication between learners on location and learners in the classroom. Furthermore, the Sydney Olympic Park Project (Brickell, Herrington, & Harper, 2005) is a more recent blended learning example. In this sense, mobile technology can be seen as a mediating artefact (Sharples, Taylor, Vavoula, 2007) that (1) can be used to give more structure to informal learning, and (2) integrates informal learning into blended learning scenarios.

The combination of learning inside as well as outside the classroom calls for a range of different, specialised devices, each suited for a specific learning use and provided with device-specific client software wielding their potential for learning. Moreover, blended learning scenarios call for software integrating the use of these devices. With the introduction of new multi-faceted devices the possibilities for content creation, delivery, and sharing across different learning contexts has been possible.

Mobile devices facilitate personalised and contextualised services that provide new ways of supporting, for example, authentic and workplace learning situations (Collins, Brown, & Newman, 1989; Schön, 1983; Sticht, 1975). In addition, mobile technology can be used to engage the learner and include her in the social and cultural aspects of that learning process (Bruner, 1996; Piaget, 1970). However, some learning content can be better used on devices with larger screens, like desktop PCs and smartboards, which provide better opportunities to display and create larger pieces of content.

Still, although blended learning scenarios are seen more frequently, it does not seem to be adapted on a larger scale in modern-day teaching. More importantly, most of technology use in education is seen as interrupting education (Sharples, 2003) and the potential of it is therefore often discarded. Additionally, the technology itself can provide an insurmountable hurdle: for instance, the mobile market contains lots of different devices without much standardisation, which leads to a need for detailed technical knowledge to be able to integrate mobile technology in existing learning scenarios. Moreover, the rapidly changing technologies form an additional burden to keep the learning scenarios up-to-date; even worse, while most learning designs would remain the same and would need similar functionality, this would have to be implemented again and again for new technology. Last, small-scale experiments could be used to create enthusiasm and show the benefits of mobile, ubiquitous, or blended learning to teachers, learners, and institutions. The creation of such experiments calls for flexible and fast prototyping, and by giving the opportunity to create and integrate learning technologies fast and without too much effort, the number of applications would increase, making room for new and innovative learning approaches.

Thus, we believe the issues preventing a larger scale adoption of new technology for learning could be mostly tackled by simplifying the use, as well as, the integration of learning technologies in modern day education. In our opinion, a standardised, technology-supported process of installation, use, and integration would benefit a larger scale adoption of multi-platform learning systems and makes it possible to reuse and adapt existing learning designs in multiple learning contexts. Certainly, ease of use would lead to a greater enthusiasm to adopt new forms of education, which in its turn could increase the frequency of use. Therefore, we will illustrate a standardised process of creating authentic, blended, and ubiquitous learning scenarios and describe a technical infrastructure to help design these scenarios. More importantly, the technical infrastructure will provide generic interfaces and components that should ease the use with a range of devices and, furthermore, hide the technical details to reduce design complexity.

However, the design of an infrastructure for multi-platform, ubiquitous learning has to be grounded in theory. Consequently, in the next section, section two, we will first consider existing Learning Networks, the underpinning pedagogical theories, and how the pedagogical scenarios used could be extended with mobile devices. Section three describes an extension to Learning Networks to support blended learning with authentic real-world scenarios, which subsequently leads to technical requirements that will be described in section four.

LEARNING NETWORKS

Learning Networks (Koper, & Tattersall, 2004) are social software that support networks of lifelong learners, focusing on communities of self-directed learners. More importantly, they mean to exploit the heterogeneity of learners by creating communities where novices and experts can collaborate. Learning Networks are founded on a combination of social-constructivist theories, more specifically, lifelong learning theories that integrate informal and formal learning approaches. Hence, to facilitate this integration, Learning Network software concentrates on supporting:

- Self-directed learning
- Learning in communities-of-practice
- Learning content creation, organisation and delivery

In the next subsections, we will shortly consider how Learning Network software supports these three settings, and see how learner support could be extended with mobile technology in a multi-platform e-learning system. In addition, we look at blended learning theory to extend current pedagogies in Learning Networks to include more authentic, real-world scenarios. After all, lifelong learning is learning anywhere and anytime and a supporting platform should ideally combine a variety of learning technologies to get the best out of each learning opportunity.

Self-directed learning

A lifelong learner is most often a self-directed learner (Brockett, & Hiemstra, 1991). Therefore, Learning Networks provide help for learners to self-organise their learning. A specific example of learner support are recommender systems that help learners deriving a learning path, a sequence of units of learning that would ultimately result in acquiring a learning goal (Drachsler, Hummel, & Koper, 2008). Another example of assistance for self-directed learners is assessment support that helps them position themselves on a learning path; i.e. which units of learning do they still need to carry out, and which ones they can skip (Kalz et al., 2007). Fur-

thermore, Learning Network software assists these learners to reflect (Schön, 1983, 1987) about their learning by preserving their growth in competency (Koper & Tattersall, 2004). The learners *controlling* their own learning process is also specifically mentioned as a part of a task model for mobile learning presented in (Taylor, Sharples, O'Malley, Vavoula, & Waycott, 2006); thus, mobile learning could provide new ways of self-directed learning by facilitating learning content access nearly anyplace and anytime.

Learning in communities-of-practice

Next to self-directed learning, Learning Networks, as the name already states, support learner communities on a certain topic. The pedagogical theory underlying Learning Networks is mainly given by Wenger and Lave (1991) who stressed the importance of knowledge acquisition in a cultural context and the integration in communities-of-practice. Bruner (1996) additionally states that learning should include social and cultural aspects. Hence, Learning Networks are social software for learning that provide several mechanisms to build, support, and maintain community processes in such communities-of-practice, among the most important are the following.

First, *collaboration:* Wenger and Lave (1991) stated that learning requires collaboration, preferably in a heterogeneous group of learners, where novices can learn by interaction with experts. Communities in Learning Networks provide a central place for people to collaborate on joint learning tasks. Especially, these communities play an important role in finding appropriate peers to collaborate with and ideally lead to learners helping each other out.

Second, another important mechanism is technology-assisted *community reflection,* which allows a learner to find suitable learning peers*,* but also contrasts the learner's own experience to that of the community. Community-reflection makes it possible for learners to find experts to learn from, help out less experienced learners, or collaborate with learners that have similar backgrounds and are facing similar problems in their learning. For this reason, Learning Networks preserve a learner's action history, more specifically a record of their competence development, which can be used to position themselves in relation to others in the learning community. This is one type of social awareness, which is aimed at sparking and maintaining active collaboration. Whereas Learning Networks provide technical assistance to raise social awareness, most of this assistance is meant to support web-based communities. In this sense, mobile technology could provide a link to real-world settings; an interesting approach being the BlueAware system presented

in Eagle and Pentland (2005), which raises social awareness by notifying users when someone with similar interests is nearby.

Third, Learning Network software encourages *communication* between learners. Pask's conversation theory (Pask, 1975) states that learning occurs by using conversations to make knowledge (more) explicit. In addition, Wenger and Lave (1991) endorse the importance of communication by articulating that learning requires social interaction between peers. Moreover, according to Cognitive Flexibility Theory (Spiro, Feltovich, Jacobson, & Coulson, 1992; Spiro & Jehng, 1990), learning activities must provide multiple representations of content and support context-dependent knowledge. Especially, the theory identifies the importance of using interactive technology to support the learner in the learning process. The various opinions of learners represent multiple perspectives on learning content. Therefore, Learning Networks offer several communication channels between peers; this makes various forms of reflection possible, for example, learning by comments made by a peer, or learning by creating comments on knowledge created by another learner. One way mobile devices can extend the range of possibilities is by allowing communication between situated learners in an authentic learning situation and decontextualised learners in a classroom or Learning Network (Terrenghi, Specht, & Stefaner, 2004).

Learning content creation, organisation and delivery

In a review of new learning and teaching practices, Nesta Futurelab identified several pedagogical theories underpinning current learning technologies (Naismith et al., 2004). One specific role of technology they found was assisting learners and teachers in coordinating learning and resources in learning activities. In Learning Networks, the coordination is mainly aimed at supporting self-directed learning and learning in communities of practice as we already have seen before. Next to that, Learning Network software makes available means to coordinate learning content creation, organisation, and delivery.

Learning content creation: constructivist theory (Bruner, 1966) brings forward learning as an active process, in which learners should construct new ideas or concepts based on their current knowledge. Moreover, learning has to take into account experiences and contexts that make the student willing and able to learn. Learning Networks consist of learners that create their own learning content and provide that learning content to be used and improved by the community. Mobile and instant creation of learning content with associated context information, like for example GPS coordinates, provides unique possibilities to add authentic learning content to learning communities.

Learning organisation: several pedagogical theories emphasise that instruction must be structured to be easily grasped by the student (Brockett & Hiemstra, 1991; Bruner, 1966, 1996). Furthermore, learning must not only be planned structured by a curriculum but also by the tasks and learning situations, and the interaction with the social environment of the learner (Wenger & Lave, 1991). Learning Networks offer extensive support to organise learning based on units of learning, learning paths and pedagogical scenarios specified in IMS-LD (Drachsler, Hummel, & Koper, 2008; Koper, Olivier, & Anderson, 2003; Koper, & Tattersall, 2004). Related to that, cognitive apprenticeship (Collins, Brown, & Newman, 1989) stresses the importance of structuring authentic learning processes to guide learners towards appropriate levels of knowledge by a constant process of contextualisation and de-contextualisation of knowledge. An interesting example providing learning organisation in a lifelong learning scenario that includes mobile devices is given in (Vavoula, & Sharples, 2002).

Learning content consumption: from a constructivist point of view knowledge is always contextualised, e.g. learning is always situated within its application and the community-of-practice (Mandl, Gruber, & Renkl, 1995). Furthermore, approaches like reflection in action and reflection about action describe the relevance of the context for enabling learning and self-reflection (Schön, 1983, 1987). While learning in Learning Networks is contextualised in the sense that it is situated in communities of practice, learning content is still mostly presented out of its situational context; i.e., the authentic context the knowledge needs to be applied in. An extension to contextualised mobile media could help to assist the learner in these authentic situations, by tailoring information delivery to an authentic learning context (Bardram & Hansen, 2004; Klopfer, Squire, & Jenkins, 2002; Ogata & Yano, 2004a).

Blended learning scenarios

The integration of formal and lifelong learning approaches with informal learning activity support in Learning Networks is currently investigated in the TENCompetence project (Koper, 2005). While the Learning Networks in this project provide multi-platform access to learning content, and hence the possibility to implement blended learning scenarios, the project focuses on web-based and desktop delivery of learning content. With the recent uptake of mobile devices (Castells et al., 2007), mobile information access has become more and more important. In addition, this new technology's impact on communication and learning in the younger generation is described as highly relevant for new forms of learning support (Green & Hannon, 2007). However, the integration of mobile device technology and other new learning media with Learning Networks, such as smart phones, tablet PCs, smartboards,

and gaming consoles, is mostly left out of scope. Moreover, the contextualisation of the learning content is limited. Since mobile devices offer unique possibilities for contextualised content creation and delivery, an extension with mobile devices would therefore offer the possibility to add real-world, context-specific learning scenarios in Learning Networks.

Several experts have indicated that learning should happen in relevant scenarios, situations, or contexts. Wenger and Lave (1991), for example, state that learning in a community-of-practice should use authentic tasks and learning situations, i.e., settings and applications that would normally involve the knowledge learnt. Sticht (1975), shares their emphasis in addressing the need to make learning relevant for the work context. Moreover, he states that the assessment of learning requires a context/content specific measurement. Related to that, Piaget (1970) highlights that learning should take place with activities or in situations that engage the learners and require adaptation. Teaching methods should be used that actively involve students and present challenges to the learner.

In chapter 2, a literature review of mobile contextualised software was presented, in which the authors made apparent that mobile devices have already been used to a large extent for social learning appliances. In particular, five application types of mobile social software for learning were exposed:

- Sharing content and knowledge
- Facilitate discussion and brainstorming
- Social awareness
- Guide communication
- Engagement and immersion

As we can see, the emphasis of mobile social software is quite similar to those of Learning Networks. A multi-platform learning system combining Learning Networks with mobile devices seems straightforward to create. In such a multi-platform approach to learning the benefits of both approaches would come together: on the one hand, self-directed learning and learning in communities-of-practice supported by the Learning Networks software. On the other hand, the learning content and learner interaction in Learning Networks can be extended with authentic, real-world creation, delivery, and interaction via mobile devices. In this way, blended learning scenarios could be created, integrating a range of technology, using the best technology to support a certain task in a certain situation or context: for instance, a mobile device to support on-the-spot learning in a fieldtrip, or a smartboard to display learning content to a classroom full of learners.

A blended learning scenario that integrates mobile learning combines de-contextualisation and contextualisation of knowledge; theoretical knowledge learnt in a classroom setting could be transferred into practical knowledge in a real-world scenario. Moreover, through using context information, in combination with the creation or retrieval of learning content, several educational effects can be achieved:

- *Multiple perspectives on real-world object*s: by viewing and creating content in a real-world context, several opinions can be perceived and expressed, from which people can benefit through an indirect learning process (Efimova & Fiedler, 2004).
- *Community-generated content* connected to relevant real-world objects and locations; an example for the effect and importance of self-generated contents in a learning community is presented in Brandt et al. (2002) about learning to operate medical devices.
- *Community interaction* and the creation of communities of interest around certain objects and locations, supporting contextualised learning (Wenger & Lave, 1991).
- *Different views on objects based on personal preferences*. Real-world objects can also be linked electronically to create relations between those objects and to create a so-called "internet of objects" (Mattern, 2004).
- *Recording of learning events;* allows for later reflection and eliciting of expert's knowledge, carried out in a work context during or shortly after the actual action performed (Schön, 1983, 1987).
- *Learning content tailored to a specific learning activity*; in the sense of cognitive apprenticeship (Collins, Brown, & Newman, 1989) the learner is guided towards appropriate levels of knowledge by a constant process of contextualisation and de-contextualisation of knowledge. Cognitive apprenticeship furthermore assumes this guidance takes place in an authentic learning situation.
- *Increasing motivation through active learning*, by actively involving the learner in the learning process, the learner involvement and motivation is increased. This as opposed to passive learning in a formal, classroom setting (Bruner, 1966).

Summarising, contextualised media enables the learner to create, retrieve, and use digital media in a relevant real-world context for notification, documentation, problem solving, reflection, communication and a variety of other learning activities. In the next sections, a technical extension of Learning Networks with contextualised mobile media will be laid out, to facilitate blended learning scenarios that combine social learning in Learning Networks with authentic scenarios in the real world.

EXTENDING LEARNING NETWORKS WITH CONTEXTUALISED BLENDED LEARNING SCENARIOS

In chapter 2, the authors have presented a reference model that can be used as a basis for future applications of mobile learning. The model will be used to extend the presented Learning Networks model to include context-aware mobile applications, which makes it possible to define contextualised blended learning scenarios in authentic settings. An overview of the reference model for mobile social software has been shown in table 3.1, which combines each of the identified dimensions with its possible values.

Table 3.1
A reference model for mobile social software for learning

Dimension				
Content	Context	Information flow	Pedagogical model	Purpose
• Documents • Annotations • Messages • Notifications	• Individuality Context • Time Context • Locations Context • Environment or Activity Context • Relations context	• One-to-one • One-to-many • Many-to-one • Many-to-many	• Behaviourist • Cognitive • Constructivist • Social Constructivist	• Sharing Content and Knowledge • Facilitate Discussion and Brainstorming • Social Awareness • Guide Communication • Engagement and Immersion

The reference model describes the type of content that is used in contextualised learning tools, the context parameters taken into account for adaptation, the information flow, and on a higher level the main purpose and the underpinning pedagogical model.

- The content dimension describes the artefacts exchanged and shared by users, in an analysis of the literature the main types of artefacts found were annotations, documents, messages, and notifications.
- The context dimension describes the context parameters taken into account for learning support. The main context dimensions identified are based on an operational definition of context by Zimmermann, Lorenz, and Oppermann (2007).
- The information flow classifies applications according to the number of entities in the system's information flow and the information distribution.
- The pedagogical paradigms and instructional models describe the main paradigm leading the design of contextualised media and the integration of media in real world contexts.

- The purpose describes applications according to the goals and methods of the system for enabling learning.

Using the reference model, mobile learning systems can be compared and classified by looking at the five dimensions; while one system could combine documents and annotations with locations context and a one-to-one information flow to support a learner in self-reflecting on the actions carried out in a specific location, another one with a many-to-many information flow would enable community-reflection for a group of learners. Thus, on the one hand, the reference model describes the manipulated knowledge resources, the context in which they are used, and the different flows of information. On the other hand, the higher-level concepts of pedagogical model and purpose define how the content, context, and information flows are used and combined. The combinations of different values for each dimension lead to various forms of contextualised software with different purposes and different pedagogical underpinnings. Yet, the five dimensions should be seen as fairly independent. Despite the fact that they can be used to classify and derive applications of mobile learning, a specific combination of context, content, and information flow does not clearly specify the pedagogical model or purpose of the application. Still, some combinations of dimensions may be encountered more often than others for a certain pedagogical model or purpose. As an example, a system with a main purpose of *sharing content and knowledge* between its users, will most often use *documents* from the content dimension, *relations context* to describe social relations between the users, and a many-to-many information flow. Likewise, a social constructivist system like RAFT (Hine, Rentoul, & Specht, 2003), combines on-the-spot creation and delivery of documents with locations context, and messages between learners in a many-to-many information flow for increased engagement and immersion.

Learning Network software is structured in four layers (Koper, 2005) that can be described using the dimensions content, information flow, and pedagogical model in the reference model described above. In addition then, the Learning Network model can be extended to include all aspects of the context dimension of the reference model. The four layers in a Learning Network can be mapped onto the reference model as follows:
- Knowledge Resources are reusable and self-contained pieces of learning content addressing a part of a larger course. These can consist of a variety of documents and annotations of the content dimensions.
- Units of Learning combine Knowledge Resources into Learning Designs that are underpinned by one of the pedagogical models of the reference model. The pedagogical scenarios are made up out of tasks and activities that can be described in a standard like IMS-LD (Koper, Olivier, & Anderson, 2003; Koper & Tat-

tersall, 2005). Learning designs furthermore can use the notifications of the content dimension to inform the learner about tasks and activities.

- Learning Communities consist of groups of learners interested in one specific topic and can be specified using individuality context, relations context, and the information flow between learners. Learners can communicate using the messages of the content dimension.
- A Learning Network is a collection of communities on a similar topic and can be fully described using the previous layers.

To be able to include authentic learning scenarios in the real world would entail adding several additional context parameters to a Learning Network system and extending others to include more detailed information. Most notably, a Learning Network that includes learning in the real world should be able to handle locations, time, and environmental or activity context. These three kinds of context can, together with the other forms, be combined to describe the learning situations (Dey, 2001) a learning scenario would take place in. For example, a history lesson could take into account certain historic locations that could be used to support fieldtrips to those locations. More importantly, by defining more generic situations "in a restaurant", reusable scenarios can be defined that can be used to learn in a range of similar situations.

TECHNICAL REQUIREMENTS FOR USING CONTEXTUALISED MEDIA IN LEARNING NETWORKS

However, to make a seamless integration of Learning Networks with for mobile and contextualised technologies possible, the implementation of the software for the technologies should be based on existing standards and should additionally take into account the following requirements. Multi-platform e-learning systems need to provide access to learning content from a wide range of devices, which requires a flexible technical infrastructure that is focused on *standardisation* and *reusability*. Technical standardisation will make the integration with existing learning management systems easier, and simplify the exchange of information between different devices and technologies. A client-server architecture adhering to existing web service standards is another kind of standardisation that will ease the interaction between heterogeneous devices and enable distributed technology (smartphones, iPods, desktops, smartboards) to communicate in a standardised and similar way.

All in all, standardisation is important because of information interchange between a variety of systems. In addition, standardisation makes the reuse of content easier. Next to the reuse of the learning content itself, pedagogical scenarios that integrate several situations, technologies, and learning theories should be written in reusable

learning designs, specified in a standard like for example IMS-LD (Koper, Olivier, & Anderson, 2003; Koper & Tattersall, 2005). *A modular server architecture*, in which new functionality can easily be added and integrated within existing learning designs, would increase this reusability.

Accessibility on different platforms calls for generic technical interfaces that make the system accessible from multiple clients. Additionally, accessibility requires adaptation of content to specific platforms; content created on one platform ideally should also be accessible using another. However, not all content is suitable to be displayed on all devices. Therefore, a technical framework supporting multi-platform learning approaches requires a certain flexibility providing *learning content filtering* and *learning content adaptation* to handle various formats and sources of learning content. The learning content should be specified in a device-independent XML format, which can be easily translated to a standardised content mark-up language to be rendered for display on various devices.

In addition, *the independence of (mobile) client technology* is important because it allows for a more heterogeneous user group and to some extent circumvents the demands of rapidly changing/aging technology. The use of web-based content furthermore makes it possible to use *lightweight, easily portable clients* that integrate a web-browser to display the learning content, and provide device-specific software to provide access to sensors. Next to this, specialised clients could be used for educational uses with a higher demand, when high performance is needed and the strengths of the technology should be exploited.

Finally, the multi-platform e-learning systems should be *easy to use*. This applies to the usability of the client software, but also to the integration of the technology in existing education. One way to realise the latter, is the use of tools aimed at a specific user groups. We propose at least two different user groups: first, one technical user group that manipulates and aggregates lower level information into higher-level educational concepts. Second, we suggest an educational practitioner group that uses the educational concepts defined by the first group to create sound pedagogical scenarios. The design of a pedagogical scenario using multi-platform e-learning systems should be left to educators, and therefore requires tools that operate on pedagogical concepts that those educators are familiar with. In any case, educators should not be bothered with technological details, and should work with higher-level concepts and components designed by people with more technological knowledge.

Technical User group

The technical user group creates higher-level educational concepts for the educational practitioners. These concepts are created by defining aggregations of context information that has been acquired using the sensors. Moreover, certain actions can be defined using actuators. Ideally, the technical user group would combine existing software components without writing any code. The creation of components should be a special case that only occurs rarely. Instead, the technical user group should be provided with two kinds of tools: (1) a visual aggregation tool that allows them to combine the components graphically, and (2) a rule-base architecture that makes it possible to define more complex component aggregations based on logic conditions about component inputs and outputs.

The technical user group uses the tools to specify both *situations* and *activities,* which can be used to define pedagogical scenarios. Situations are specified by an aggregation of context parameters and values and give the conditions in which a certain activity *can* or *should* take place. Conversely, activities specify certain actions or combinations of actions that should influence or drive learning (Koper, Olivier, & Anderson, 2003; Koper, & Tattersall, 2005). In a driving instruction scenario, a situation and activity could be defined as follows: to teach a student operating the vehicle not to drive too fast, a *situation* called "speeding" could be created that combines the two context *parameters* of time and location. Using the context *values* of these parameters the speed of a person can be calculated. Based on a *condition* defining the situation of "speeding", a decision can be made whether or not to carry out an *activity* that teaches the person what reaction is needed to prevent the person from driving too fast.

Educational Practitioner group

An educational practitioner designs the pedagogical scenarios aimed at a specific learning content domain. Unlike, the technical user, an educational practitioner should not be bothered with technical details, like aggregations of sensor information and how to define situations on the basis of context parameters. Instead, an educational practitioner should be presented with known pedagogical and domain-specific concepts.

Pedagogical scenarios can be defined using learning designs that can be specified using standards as IMS-LD (Koper, Olivier, & Anderson, 2003; Koper & Tattersall, 2005). Learning designs use a combination of activities and learning content to create a variety of pedagogical scenarios. A lot of standardised activities are present within Learning Networks, among others the following examples:
- *the study* of learning theory,

- *on-spot content creation*; for example mobile content gathering,
- community-reflection on created content,
- *situation-specific* learning content delivery,
- introduction to suitable learning peers,
- collaboration,
- discussion with peers.

To create technology-mediated authentic learning scenarios, the situations in which these activities take place should be furthermore specified. In this case, three different conditions can take place. First, a situation could be pre-condition to an activity; thus, an activity will be sparked when a learner takes part in a situation. Second, a situation could be a post-condition that could be the result of an activity. Third, the situation can be monitored during an activity. By using this combination of activities, situations and learning content, complex learning scenarios can be created, two of which we will describe in chapter 5.

CHAPTER 4
A Technical Framework for Contextualised Learning

ABSTRACT

This chapter will present a generic technical framework for lifelong and informal mobile learning. The technical framework is based on the reference model in chapter 2 and the technical requirements given in chapter 3. The reference model should provide a foundation that leads to a flexible and generic technical framework that can be used in a range of different learning scenarios. Moreover, a generic technical approach should aim at an easier integration of contextualised learning appliances into current learning. To test certain functionality of the generic technical framework and evaluate mobile learning support in the real world, a concept implementation of the technical framework was developed. The so-called ContextBlogger software is a client-server architecture with several types of mobile clients that are also described in more detail.

INTRODUCTION

In chapter 2, the authors have already explored a lot of combinations in the state-of-the-art in mobile social software. During this exploration also some limitations of mobile contextualised learning solutions have become clear. Summarising the following extensions to current state-of-the-art can brought forward based on these limitations:

- provide more integrated systems with a range of functionality,
- better and wider use of metadata,
- more advanced and wider use of notification techniques,
- an improved adaptation to the user's personal preferences and learning environment or situation by using more kinds of context information than location and identity alone, and use of techniques to derive more detailed or higher level context information by a combination of different context parameters,
- more attention to systems aiming at informal and lifelong learning.

With the reference model, these extensions, and the requirements given in chapter 3 as guidelines, we propose a generic technical framework for contextualised media for learning. The wide range of possible contextualised learning scenarios requires a flexible technical framework. The framework should offer support for on the spot content creation and delivery and should make it possible to combine content and context information in addition. Therefore, we propose a framework that consists of a context management part and an independent part, handling different types of contents on an abstract level. The context management part will be based on already existing infrastructures for context management. Zimmermann, Lorenz, and Specht (2005) suggest a standard architecture for context management that seman-

tically enriches contextual data step by step in successive layers, which will be used as our main guideline.

The system should integrate the use of content with the use of metadata, make it possible to combine different kinds of context information into higher level information, and enable the design of higher level processes based on this context information and the available content. Additionally, the technical framework should take into account the reference model presented earlier. Figure 4.1 shows an overview of the technical framework comprised of a multi-column model with four layers.

On the one hand, the four layers represent the several forms of data used in the system; from unstructured, raw data in the lowest layer to highly structured and enriched data in the topmost layer. On the other hand, the three columns identify the different kinds of artefacts that can be used in a learning process: the context metadata identifying the learning situation, the electronic media used in the learning process (context and content in the reference model), and the physical world objects the learners interact with during that learning process. The two leftmost columns (context and content) are modelling the physical world in the rightmost column. The artefacts used and manipulated in each of the columns will be described in more detail in the subsections below. Finally, the event-bus used for communication throughout the framework is described and some suggestions for a technical implementation given.
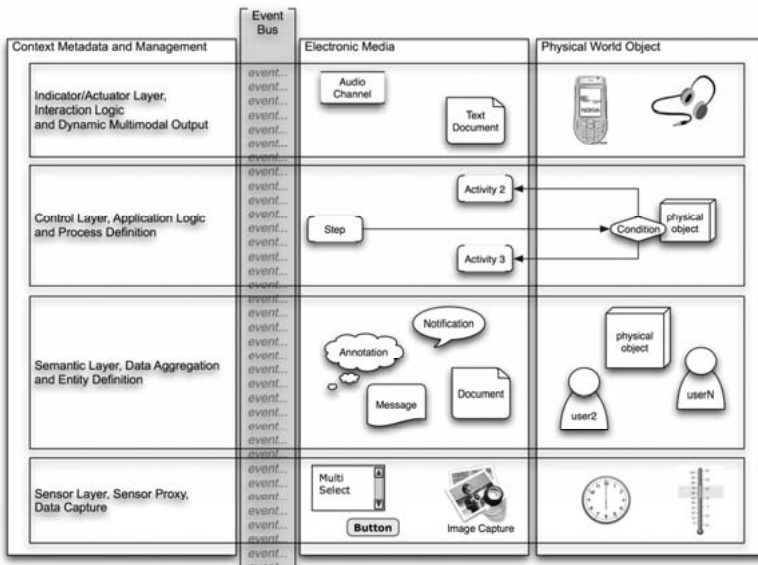

Figure 4.1: The contextualised media framework, its layers and entities

Context Metadata and Management

The leftmost column in figure 4.1 will be aimed at acquiring and managing context metadata. Context information is acquired through sensors and can be further enriched to more detailed information about a learning situation. The situation will be described using context metadata in one or more of the five categories of context information of the reference model:

- Individuality context includes information about objects and users in the real world as well as information about groups and the attributes or properties the members have in common.
- Time context, this dimension ranges from simple points in time to ranges, intervals and a complete history of entities.
- Locations context is divided into quantitative and qualitative location models, which allow working with absolute and relative positions.
- Environment or Activity context reflects the entities, goals, tasks, and actions of a user.
- Relations context captures the relation an entity has established to other entities, and describes social, functional, and compositional relationships.

This contextual information can be used to describe or derive information about the user (describing for example the learner's personal preferences), information about the environment, (describing the learner's physical environment) or, information about the social context of the learner (describing the social relationships a learner is involved in and the social networks the learner is part of). The sensor data, representing various complexities or combinations of these five categories of contextual information, is captured in the lowest layer. Each subsequent layer will enrich the sensor data more, until an action responding to the current context can be carried out. The second layer, or semantic layer, contains low level rules that combine sensor data into higher-level context information. For example, using a combination of individuality context, time context and locations context, relations context can be derived, identifying which users are interacting at a specific time and place. Another example is the calculation of the user's speed by combining location and time context. After semantically enriching the sensor data, the third layer (the control layer) defines high-level application logic that can model the actions that have to be taken on the basis of the current context information. These rules define what we call *Content-Context Modelling*, which models the adaptation of learning content to context information, identifying a certain learning context. For instance, a rule giving a notification to draw attention to a location, object, or other learner can be created. The fourth layer, the indicator/actuator layer, chooses the indicator or actuator that is best suited to carry out the action from the control layer or display

the learning content chosen. If, for example, the noise level is too high for people to hear an audio feedback, the layer could decide to provide visual feedback instead.

Contextualised Electronic Media

The middle column of figure 4.1 handles all kinds of electronic media, a combination of which can be found in most learning content. The lowest layer provides several mechanisms of media input by the learners, for example, image capture from a mobile device or text input from a web-based widget. The second layer manipulates several kinds of electronic media, based on the four types identified by the reference model: annotations, documents, messages, and notifications. Several kinds of input from the first layer can be combined to form one of these for types of content. For example, a text input together with an audio message forms a multimodal annotation. Furthermore, the second layer also stores and retrieves the electronic media in/from the content repositories.

The third layer defines activity models that define learning activities and the combination of content, information flows, and learner roles. Educational processes can be modelled on the basis of these activity models and pedagogical paradigms from the reference model. The educational scenarios will be modelled in IMS Learning Design (IMS LD; Koper, Olivier, & Anderson, 2003). By providing an interface to the context metadata and management system, the educational scenarios are able to use context information about the learner and his environment. Thus, context information can be used to drive the modelled educational process into a specific direction. Moreover, physical world objects, real-world locations, and detailed information about the user and his social environment can be integrated to support learning. Hence, real-world situations and objects can be described using the context information and electronic media. Finally, the last layer chooses, on the basis of the electronic media that has been selected by the educational process modelling, which output channel should be chosen, i.e. the audio channel of a mobile phone or a Smartboard display to output a text document (see figure 4.1).

Physical world objects

The third and rightmost column is not part of the technical framework as such. However, it helps in identifying which concepts can be used in current learning processes. For example, the lowest layer describes units that can be measured by the sensors of the context metadata and management system, i.e. speed or temperature. The second layer identifies which users and which real-world objects can be used in an educational scenario. These objects can be equipped with tags that help in detecting their current context; the barcodes, RFID tags, or information from a

Global Positioning System (GPS) to facilitate context-detection are described in the third layer. The tags make it possible to attach electronic media to real-world objects or locations. The fourth layer describes artefacts that can be used to mediate learning or to reach the learner, like for instance a mobile phone to display content and acquire context information or a wireless headphone to be able to stream audio content information to the learner at a specific location.

Event bus and technical implementation

For an extensible and flexible framework, we are using a service-oriented architecture, consisting of a server and several clients that provide the sensors and actuators (Rehrl, Bortenschlager, Reich, Rieser, Westenthaler, 2004). In addition, an event bus is used for all interlayer communication; functional components can register for events published by other components and are notified whenever such an event occurs. On notification, the component carries out an action as reaction to the event, which may result in new events being published. For instance, a sensor can post a *sensor update event* with new sensor values on the event bus, which will be picked up by other modules listening to sensor updates. The technical framework will be released under an open source licence and use existing open source software as a foundation.

A TECHNICAL FRAMEWORK FOR CONTEXTUALISED LEARNING

The technical framework described would allow us to (1) model different educational applications based on three dimensions of content, context and information flow and (2) implement these educational applications in a standardised way with minimised effort. As a proof of concept an integrated application of mobile social software for learning called the ContextBlogger was developed, which demonstrates certain functionality of the framework described above. The ContextBlogger mobile software couples learning content to physical objects or locations in the real world.

ContextBlogger combines social software with information about the context of a learner. The information in the system can be accessed using a mobile device, and the content can be filtered through the application of search filters based on context information. The search filters for the ContextBlogger application retrieve the content either related to a specific real-world object or to a specific user location. Furthermore, the learner can also choose to create his/her own content and relate it to a real-world objects or locations. Therefore, the use of the ContextBlogger application provides a basis for an investigation of the usage of physical artefacts in

learning. On the one hand the combination with a physical object could provide the basis for learning, on the other, shared objects could be used to build communities of practice (Wenger & Lave, 1991) and couple the creation of Learning Networks to physical objects. In addition, a number of aspects of mobile social software are integrated in the software. First of all, multiple users can use their mobile devices to create and insert multimedia into a shared web space or view the information added, because every object preserves its own history. Second, ContextBlogger has a social community surrounding it that rates and annotates the learning content. This facilitates community feedback on information provided and around a physical object.

Through applying different context filters in combination with the creation or retrieval of learning content, we expect to achieve different educational effects:

- *Multiple perspectives on real-world objects*: by viewing the object's history, a certain category of learning content, or using other filters people benefit through an indirect learning process (Efimova & Fiedler, 2004; Walker, 2005). Real-world objects can also be linked electronically to create relations between those objects and to create a so-called "internet of objects" (Mattern, 2004).
- *Community-generated content* connected to relevant real-world objects and locations: an example of the effect and importance of self-generated contents in a learning community is presented in Brandt et al. (2003) about learning to operate medical devices.
- *Community interaction* and the creation of communities of interest around certain objects and locations, supporting contextualised learning.
- *Increase motivation through active learning,* by actively involving the learner in the learning process, the learner involvement and motivation is increased. This as opposed to passive learning in a formal classroom setting.

To achieve these educational effects, the underlying concepts of a system for contextualised blogging and the relations between them should be analysed. For instance, to create *multiple perspectives on real-world objects and locations*, a user should be able to interact with a physical object and should be able to retrieve content linked to that physical object. By using shared real-world objects, multiple users can interact with them, and create information objects related to them or view, rate and comment the content added by other people (*community-generated content)*. In that way, a community of users can evolve around these shared objects and the *community interaction* leads to different opinions and perspectives about these objects. The multitude of perspectives about a shared object, can lead to either a discussion between users with different opinions or leads to reflection about a situation by the learner; either by looking at the opinions of other users, or by adding content and reading it back later, as an opportunity to reflect back on what

happened before (Schön, 1983, 1987). To prevent the user from being over-whelmed by the amount of information available in a community, contextualised search filters are used that only display the relevant information for a certain situation or context. By combining these educational effects the system addresses the lifelong learner, by providing several opportunities for the self-centred learner or a community of these learners to structure the learning process. Also the system relies on the implicit assumption of lifelong learning that responsibility for the creation and structuring of learning content resides with the self-directed learner himself (Koper & Tattersall, 2004). The developed ContextBlogger architecture will be described in more detail in the next section.

THE CONTEXTBLOGGER ARCHITECTURE

Figure 4.2 shows an overview of the implemented ContextBlogger Architecture. Three main components can be distinguished: the context system, the content and metadata system, and the user management system. First, the context system is an initial implementation of the Context Metadata and Management of the technical framework presented in this chapter. The context system entails the most basic functionality specified in the technical framework, which allows the specification of context metadata for the learning content in the system. Additionally, it can deliver learning content to the learner on the basis of certain context information provided. Three types of context information can be distinguished in the architecture: object-identity context that identifies objects in the real-world, location context that represents real-world locations, and time-context that identifies the moment a certain resource has been created or last accessed. Second, the content and metadata system manages the learning content that consists of several types of multimedia. In addition, this system stores various types of metadata about the learning content. For instance, learning content can be annotated with tags and categories to provide a higher-level organization. Moreover, learners can comment and rate existing learning content. Last, the user management system provides authentication services and stores basic information about the learners in a user profile. Furthermore, this system identifies the learners that created certain learning content. All three main components use a database to store the information used.
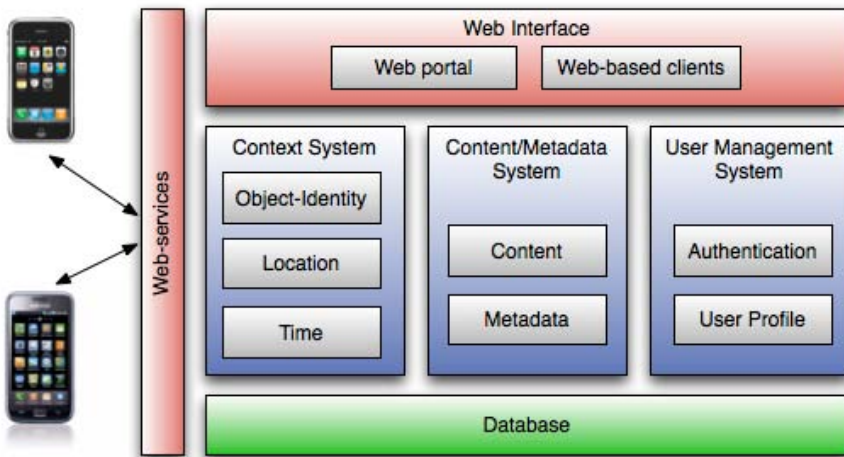
Figure 4.2: An overview of the components of the ContextBlogger Architecture

The information in the ContextBlogger architecture can be accessed in several ways. On the one hand, a web interface delivers the information in such a way that it can be accessed in a web browser. Depending on the type of client, the information is rendered as a full-featured web page that can be accessed via a web browser on a desktop machine, or as a web page adapted to be viewed on small screens for a web browser on a mobile device. On the other hand, information can be accessed in a client-server setup, via web services (REST and SOAP) with a variety of mobile clients. The different mobile clients that were implemented for the ContextBlogger architecture will be described in the next section.

MOBILE CLIENTS

As part of the ContextBlogger architecture, three kinds of mobile clients were developed that are also encountered in the literature. First, web-based clients use the mobile browser to access a webpage optimised to be viewed on mobile devices. Second, native clients provide on-device software that is written for a specific type of device to make use of the characteristics of and optimisations for that device. Third, hybrid clients were developed, which are a combination of the former two clients, combining device-specific features with web-based content.

Web-based clients

The web-based clients access learning content, in the form of web pages, via a mobile Internet browser. The software providing the learning content runs on a server and is not present on the mobile device itself. Therefore, web-based clients need a constant connection to the Internet to retrieve the learning content. Using the developed client learners are able to access multimodal learning content (text, pictures, and audio) represented in web-pages optimised for use on a mobile device. An advantage of web-based clients is that the learners do not have to install software on their mobile device and can access it using standardised browser software; the web-based content can be viewed on a variety of devices and can be updated fast. Moreover, to develop the learning content in a web-based language, like for instance HTML, no or very limited specialised knowledge of the mobile devices is required. However, because the mobile device needs a constant connection to the Internet web-based clients can still be expensive for the learner, and can cause problems when the connection is unreliable or slow. In general, web-based clients are slower than the native clients presented in the next section. Especially, high-bandwidth content, like audio and video, is not encouraged when used outside reliable and fast WIFI networks. In addition, the web-based clients are only able to access device-specific features on a limited scale or not at all in the worst-case scenario, which restricts them in providing innovative uses of device-specific sensor and actuator hardware.

Native clients

Two types of native clients were developed. The first type of native clients, the online clients, retrieves the learning content from a server when needed and therefore needs an active connection to the Internet. The second type, the offline clients, store the learning content on the mobile device itself; the learning content is either provided at time of deployment, or downloaded from a server before the learning takes place.

Online clients
The online clients download the learning content at the moment it is needed; the learning content can thus be provided just-in-time. Therefore, the online clients are especially fit for learning contexts in which the learning content changes often or fast. Since these native clients can access the mobile device sensors directly, information about the learner context can be retrieved. The combination of fast and flexible content access and the context information from the sensors makes the online clients suitable for situations where learning content should be delivered just-in-time and adapted to the learner's context.

Online native clients have several advantages. First, the online clients are native software on a device; they can use device specific optimisations and are therefore quite fast. Second, because the online clients retrieve the learning content when needed they are quite flexible; learning content can be updated fast and learners can directly see actions carried out by their peers. Third, device sensors can be accessed to retrieve information about the learner context and used to adapt to the learner's current situation and interests. Last, a rich variety of content (text, audio, pictures, video) meta-tagged with context information can be generated using the device hardware. In contrast, the online clients have similar disadvantages as the web-based clients in the previous section; the constant connection to the Internet can result in expensive learning scenarios, can be unreliable and slow. While accessing high-bandwidth content can be also be problematic, the online clients could cache this content locally to make subsequent access faster.

Offline clients

The offline clients are also full native clients and therefore can benefit from the speed of the devices and access sensor and actuator hardware directly. In contrast to the online clients, offline clients do not access the learning content on-demand. Instead, the learning content is either (1) provided with the software at the time of deployment and does not change, or (2) downloaded in the form of content packages before it is needed, typically as a synchronisation to a desktop computer or in an environment that offers high speed connections. In addition to the speed and access to sensor information, offline clients have the advantage of storing high-bandwidth content on the device. Therefore, high-bandwidth content can also be accessed without any problems in situations where there is no Internet connection available or in places where connection quality is poor. A disadvantage of offline clients is their smaller flexibility; since the learning content is stored on the device before the actual learning takes place, the content cannot be adapted to the demands of the current learning context, and therefore offline clients provide more static content.

Hybrid clients

Hybrid clients are device-native applications that embed a mobile browser. As such, hybrid clients combine full access to the device capabilities with the flexibility of web-based learning content. A common scenario for hybrid clients uses access to device sensors to acquire information about the learner context and retrieves web-based learning content appropriate for that context. Hybrid clients thus provide an easy way to extend existing web-based learning management systems with a mobile device scenario. Hybrid clients provide the advantages of a native application with the flexibility of web-based learning content. On the one hand, they provide access

to the device sensors and actuators and therefore offer a way to acquire information about the learner. On the other hand, the web-based content can be developed in standardised HTML and reused from or for other purposes. However, since hybrid clients use web-based content, similar disadvantages as for web-based clients apply; connections can be slow or unreliable, and high-bandwidth content should not be used in situations where this is the case. In addition, the possibilities to cache learning content on-device are more limited than with full native clients.

The different mobile client types compared

To recapitalise the aspects of the different types of mobile clients, we provide a short overview here. Table 4.1 summarises and compares the advantages and disadvantages of the different type of clients.

Table 4.1:
The advantages and disadvantages of different mobile client types compared

	Client Type			
	Web-based Clients	Native Online Clients	Native Offline Client	Hybrid Clients
Speed	Slow	Fast	Fast	Medium
Flexibility	Good	Good	Bad	Good
Access to sensors	Limited	Full	Full	Full
Content Caching	Limited	Yes	Not applicable	Limited
High-bandwidth learning content	Only on fast connections	Only on fast connections	Possible in all learning contexts	Only on fast connections

CHAPTER 5

Application Scenarios of the Technical Framework

ABSTRACT

In this chapter, two application scenarios of the technical framework are described. The scenarios are part of two different application domains. The first scenario describes mobile and social support for second language learners. The idea of learning a language by interaction with real-world objects is one that will be further examined in chapters 6 and 8. The second scenario applies the technical framework to support building engineering students in both the classroom as in the real world. The creation of annotated learning content in a building engineering context will be more thoroughly considered in chapter 7.

INTRODUCTION

The contextualised Learning Network software described could be used to carry out several mobile social learning scenarios, two of which we will provide in this section. The first example will describe a second language-learning scenario, while the second will portray the benefits of blended learning scenarios in a real-world building engineering scenario. The examples will illustrate how learning in Learning Networks can be combined with authentic, more informal, and formal classroom-based learning scenarios. We will concentrate on the use of mobile devices to support learning in context. The application scenarios served as a guideline for the studies described in the next chapters.

Second Language Learning

Language is a typical example of something that is widely used across contexts. Language learning takes place in different settings, for example, in a structured setting in an official language course in an educational institution, or a more unstructured, and common day-to-day setting in which language is acquired in a random manner. Additionally, the type of language learnt depends on the situation; some require informal daily speech, while other settings, i.e. business negotiations, require more formal language. Furthermore, language learning is addressed towards a certain community, most often a community of native or near-native practitioners, which uses a community-specific jargon (Petersen & Divitini, 2005). Especially, in an increasingly international world, acquiring this community-specific language becomes more and more important. Particularly, non-native speakers have a demand for just-in-time, situation-specific vocabulary to communicate in a more effective and efficient way.

This cross-context, situation-specific, community-based, and just-in-time nature makes language learning an interesting domain to explore and illustrate the possibilities and problems of a multi-platform e-learning system. In this sense, Petersen and Divitini (2005) have identified interesting community-based scenarios that include the use of mobile devices for learning. More specifically, they emphasise that learning in communities is important because the students need to: (1) learn in an authentic cultural context where the local language is used, and (2) practice using the language with native speakers. In addition, we feel language learning would benefit from blended learning, combining de-contextualised theoretic language lessons, with contextualised authentic learning scenarios. An example of a de-contextualised language scenario is a structured online language-learning course, much like the one taught at schools that train grammar, use vocabulary lists, and structured repetition. Conversely, contextualised scenarios would tailor vocabulary- and useful phrase lists to certain situations in daily-life. Paredes et al. (2005) already demonstrated the context-aware language-learning tool, LOCH, which assists learners in tasks that have to be solved by interacting with native speakers in the real world. LOCH enables learners to directly get into contact with their teacher by using PDAs. The teacher can view the learner's locations and decide to give location-specific feedback. Moreover, the learners can create contextualised information like written annotations and pictures.

In a multi-platform Learning Network like the one we described in chapter 3, several connecting language learning scenarios can be implemented. A language-Learning Network would include a variety of different learning communities each involved in learning a different language. Each community would consist of a heterogeneous group of native, near-native, and non-native language learners that create, possibly contextualised, multilingual learning content. The creation of learning content can furthermore be combined with community-reflection where more competent learners review the work done by novices. Furthermore, learners should be helped in finding appropriate (native) peers and a community-of-practice that would help them in their learning process; in this case, it would be interesting to couple native speakers that want to learn each other's languages. In any way, active use of a language by discussing with native peers would be an important part of language learning in Learning Networks.

Next to the community learning described above, language learning would also be beneficiary to self-directed learning processes, possibly mediated with mobile devices. The developed scenarios should allow for memorisation and repetition of language constructs, help to learn from errors by self-reflection on preserved learning history, and combine de-contextualised and contextualised knowledge that results in applying the knowledge learnt. Furthermore, the Learning Network soft-

ware should help the self-directed learner in planning, structuring, self-monitoring, and evaluation of learning. Mobile devices could mediate these processes, for example by structured delivery of learning content for memorisation and repetition (Attewell & Webster, 2004). Another example is language learning by interaction with real-world objects. The objects are enriched with language learning content, for example a text message describing the object, or an audio fragment containing a useful phrase related to that object that can be accessed using a mobile device. Thus, the interaction with the objects and learning content in an authentic situation allows learners to learn a language. Furthermore, learners can create their own language learning content connected to objects, as for example with the Context-Blogger (see chapter 4).

Summarising, language learning in multi-platform Learning Networks includes the following activities:

- Acquiring language on the move, tailored to specific situations,
- Active use of the language, by communication with native peers,
- Creation of learning content, either contextualised or de-contextualised,
- Commenting on peers,
- Discussion with peers,
- Memorisation and repetition,
- Planning, structuring, and self-monitoring of learning,
- Learning by interaction in the real world.

In addition, countless situations could be defined that are used to contextualise the available language content, for instance, standard situations as introducing yourself, ordering at a restaurant, bargaining in a shop, etcetera.

A Real-World Building Engineering Scenario

In building engineering, students have to learn how to apply the theoretical knowledge in the curriculum to real-world construction work scenarios. While currently most of the teaching is theoretical and classroom-based, students would benefit by actually seeing the principles applied in real construction work. Not only does such an exploration give students the opportunity to encounter real-world examples of knowledge applied, it also actively involves the students in the learning process and compels them to apply the theory just learnt (Bruner, 1966). This application scenario gives an example to get most benefit out of practical learning situations by mediating on-the-spot health and safety risks management learning with mobile devices.

The scenario is based on a Health and Safety Management course, which is part of the International Master in Construction Project Management taught at the Technical University of Catalonia (UPC). The aim of this course is to provide basic knowledge of health and safety (H&S) risks identification, H&S preventive measures and H&S regulations. Therefore, the course provides the know-how that will enable the future construction project managers to analyse and identify the H&S risks existing on a real construction site, in a clear, concise and comprehensive way and to choose the better and more efficient preventive measures to solve these risky situations. In order for students to build a better understanding of the concepts contained in the course, it is important that all the concepts exposed in the theoretical lessons can be recaptured by the students in real-world construction site scenarios, for instance, by using smart phones capable of displaying rich media content.

The course scenario is divided in three modules. First, in module one, the instructor exposes all the theoretical contents stressing the importance of the real-world construction examples and the use of digital contents, existing in repositories in the web, easily accessible for students. Second, module two aims at developing a workshop based on a real construction site. Students are provided with drawings of the current real state of the building. Then, the group of students (maximum 15 people) is moved to the construction site, where the H&S risk manager guides them through the site. Students are asked to identify the existing H&S risks, and the applied or missing preventive measures, which they should draw on the provided drawings. Digital contents exposed by the instructor in the theoretical lessons can again be viewed by using the smart phones, which allow the owners to access their work and improve their learning outside of a normal classroom context. Additionally, students are also encouraged to take pictures of the applied or missing preventive measures to be used in a reflective session afterwards. Last, module three is aimed at collecting and sharing all the students' reflections and observations using the drawings, pictures or videos recorded during the visit.

At the end of the course, students have gone through all the theoretical concepts related to H&S management, they have been at a real construction site where the theory has been applied, and finally they are asked to assume the role of the H&S risk manager checking the security of the site. Most of the learning process can be supported by multi-platform e-learning solutions.

In contrast to the second language learning scenario, learning health and safety aspects in building engineering mainly involves:
• Learning the theory: using pre-designed units of learning about the health and safety aspects.

- Contextualised content creation: the creation of GPS annotated pictures and other learning content describing the health and safety aspect on-site.
- A reflection session in the classroom afterwards discussing the created content to learn from each other's learning content.

The Learning Network software could support the dissemination of the learning theory and the reflection session, while the contextualised content creation is typically done with mobile devices. Three different situations are found in this scenario: the pre-visit classroom-based session, the exploration of a real construction site, and the classroom reflection after the visit. These three situations can mainly be distinguished using location and time context information.

CHAPTER 6
A Study of Contextualised Mobile Information Delivery for Language Learning

ABSTRACT

Mobile devices offer unique opportunities to deliver learning content in authentic learning situations. Apart from being able to play various kinds of rich multimedia content, they offer new ways of tailoring information to the learner's situation or context. This paper presents the results of a study of mobile media delivery for language learning, comparing two context filters and four selection methods for language content. Thirty-five people (18 male, 17 female; M = 31.06 years, SD = 8.93) participated in this study, divided over seven treatments in total. The treatment groups were compared on knowledge gain, which differed significantly. The results found indicated an effect of both context filters as selection methods on the learner performance. In addition, the results indicated a cost/benefit trade-off that should be taken into account when developing contextualised media for learning.

INTRODUCTION

Undoubtedly, language is one of the most important of mankind's abilities. As Pinker (1994) puts it: "For you and I belong to a species with a remarkable ability: we can shape events in each other's brains with exquisite precision." The communication Pinker hints at is only possible if we are able to understand each other's languages; an increasingly important ability in a world that is rapidly internationalising, not in the least because modern-day technology allows us to communicate over large distances and across language boundaries. A perfect example of such technology is a mobile phone, which not only simplified and increased communication possibilities, but also led to communication virtually anywhere and anytime. In addition, these increasingly powerful handhelds, now often referred to as "smart phones", provide other types of connectivity next to voice communication, and are often used to access all sorts of information on the move. In this paper, we will explore mobile technology supporting second language learners to communicate in a non-native language.

The importance of communication in a target language has been stressed by several theories of second language learning. While each of the theories has a different viewpoint on language learning, all of them see language learning as an essential social process. First, the input and interaction theories of second language learning emphasise the role of social interaction for target language input, output, and interaction. These theories have been based two hypotheses. On the one hand, the interaction hypothesis (Long, 1981, 1983, 1996) states the importance of language interaction to increase the comprehensibility and usefulness of language input for the individual language learner. Especially, the role of negotiation of meaning be-

tween a native and non-native speaker is an essential part of the research inspired by this hypothesis. On the other hand, the output hypothesis (Swain, 1985, 1995) states that certain aspects (syntax and morphology) of a second language are most effectively developed in second language production. According to Swain, language output raises consciousness of problems and gaps in current knowledge, can provide opportunities to tests hypotheses about the second language, and allows the language learner to reflect on the language explicitly. Second, the sociocultural perspectives to second language learning are grounded in sociocultural and activity theory (Vygotsky, 1962, 1978) in which language is seen as a tool for making meaning in the collaboration with target language speakers. Thus, the sociocultural perspectives also consider language interaction but their emphasis is more on the social motive for second language learning. In this sense, the emphasis of these theories is on self-regulation through private speech to gain control over the language task (Frawley & Lantolf, 1985), the influence of personal characteristics and interests on social interaction (Coughlan, & Duff, 1994; Roebuck, 2000), and language feedback of native speakers to scaffold a second language learner (Aljaafreh, & Lantolf, 1994; Nassaji, & Swain, 2000). Last, the sociolinguistic perspectives consider the second language learner as part of communities of practice and investigate the role of the learner's identity, emotions, and social position in a learner's development of a second language (Bremer, Roberts, Vasseur, Simonot, & Broeder, 1996; Heller, 1999; Norton, 2000; Ochs, & Schieffelin, 1995; Pierce, 1995; Wenger, & Lave, 1991). Moreover, the sociolinguist perspectives see language learning as a situated activity, in which the influence of the learning context on the learner is essential. Summarising, the second language theories mentioned here all emphasise the social aspect of language learning in which both language production as language input in real-world scenarios with target language speakers are important. Thus, the possibility to access information anywhere and anytime makes mobile devices a welcome tool to support a second language learner in real-world interactions with target language speakers.

A variety of studies already investigated the opportunities of mobile devices for language learning. Kukulska-Hulme and Shield (2007) distinguish between using mobile devices in a more passive manner for learning content distribution and using them to encourage interaction of the second language learners in their target language environment. Most of the current mobile language learning studies aim at the former content distribution and offer vocabulary training in previously unused time slots, instant lookup of vocabulary anytime and anyplace, and repetition in the form of quizzes and surveys. For example, Levy and Kennedy (2005) describe learning Italian vocabulary via SMS messages that were sent at specific time intervals. Likewise, Fisher et al. (2009) provide an example of an extended e-book reader that allows the second language learner to instantly look up vocabulary and listen to a

native pronunciation. Last, Thornton and Houser (2005) investigated the effects of e-mails with English vocabulary sent to mobile devices owned by Japanese students, and described the combination of textual information (explanations, quizzes) and video material for mobile language learning. In contrary to these more passive mobile language-learning approaches, mobile learning solutions supporting target language interaction are largely left unconsidered (Petersen & Divitini, 2005). To address this lack of solutions Petersen and Divitini (2005) provide two scenarios for community-based mobile language learning, one of which focuses on interaction between students in a native and students in a non-native environment. Similarly, Kukulska-Hulme and Shield (2007) in their review of MALL also emphasise the importance of real-world interaction, and stress the lack of mobile language learning solutions for speaking and listening. An interesting example of a context-aware mobile language learning system aimed at real-world interaction is JAPELAS (Ogata & Yano, 2004a) that provides the learner with the correct Japanese politeness expressions based on a learner profile, location, and the person addressed. What's more, Ogata and Yano (2004a) present TANGO, a mobile learning system that uses RFID-tagged real-world objects to teach vocabulary. Another example of mobile support for language interaction is the LOCH system that supports second language learners to carry out tasks in a Japanese target language environment (Paredes et al., 2005; Ogata et al., 2006). In addition, the tasks carried out with LOCH were all focused on communication in the target language and were supported by a teacher that could view the GPS location of the students to give location-specific feedback.

While the research mentioned above, considers language interaction at both the object and location level, it did not explore the effects of the learner context on the interactions in the target language. Thus, the influence of using different context granularities (object-based vs. location-based) to provide second language support at varying levels of specificity is not clear. A critical question that remains unanswered is whether there are differences between the efficiency of learning support provided by object-based and location-based information delivery. Moreover, if there are any differences, are there any circumstances in which either of these granularities prove more efficient? Related to that, the context filters available can result in different forms of user interactions that may also influence the learner performance. In the study presented here, we aim to address part of these questions and present an evaluation of a language-learning tool that focuses on interaction support for second language learning. More specifically, we compare the effectiveness of object-based filters against location-based filters, and investigate the effects of several levels of mobile user interaction ranging from the users providing all context information themselves to the system automatically detecting the user's context. It is expected that the more specific object-based filter leads to a more specific interaction with the learning content, and therefore a better learner

performance. In addition, we expect that the automatic context detection will prove less of a burden on the learner and will prove the more efficient. The evaluation was carried out in a lab setting, where a number of rooms were equipped with objects according to a certain theme (market, restaurant, etcetera). In this paper, we adapt a framework for evaluating mobile learning from a technological (desirability, usability) and an educational perspective (effectiveness) that was proposed in Sharples (2009). The results of the evaluation with this framework will be presented in this paper.

METHOD

Design

This study used a between-groups design, with two independent variables: the context filter (with two levels: room filter and object filter) and the selection method used (with four levels: semacode-based, number-based, list-based, and location-based). The dependent variable was the immediate knowledge gain calculated from the number of correct answers given in the pre-test questionnaire and the post-test questionnaire.

The context filter independent variable was based on the context dimension of the reference model presented in chapter 2. The room filter delivers the learning content based on location context, i.e. the room the learner is located in. The object filter delivers learning content based on identity context, more specifically the object the learner is currently interacting with. In this respect, the location-based filter provides learning content for a more general context than the object filter.

The selection method independent variable specifies the variations of user interfaces that were used during the experiment, each with a different form of user control. Each variation acquired the context information via a different selection method: either directly from the learner (number-based or list-based), semi-automatically (semacodes), or automatically (location-based). In the number-based and list-based variations, the learner provides the context information respectively by (1) entering an object or room number in a text field, or (2) by choosing a room or object from a list with all possibilities available. The semi-automatic variations identified the object or room context by the semacode they were tagged with, and finally, the automatic variation detects the learner's room location using a location tracking system.

Each treatment variation in the study employed another combination of *the selection method* and *the context filter*, all of which are given by table 6.1. Because a

location-based object filter was not available seven instead of eight treatments were tested.

Table 6.1
Overview of the seven treatment groups that were used

	Selection method			
Context Filter	Semacode-based	Number-based	List-based	Location-based
Room Filter	SRF	NRF	LRF	LORF
Object Filter	SOF	NOF	LOF	x

The dependent variable, *the knowledge gain (KG)*, was calculated with the following formula:

$$KG = (\Sigma KQpost_i - \Sigma KQpre_i) / i, \text{ where } i = 25. \tag{6.1}$$

Equation 6.1 calculates the knowledge gain, as a ratio, by subtracting the total number of correct answers of the pre-test ($\Sigma KQpre$) from the number of correct answers of the post-test ($\Sigma KQpost$) for all participants, and dividing the results by the total number of questions in the tests i. The minimum knowledge gain is therefore 0, the maximum knowledge gain equals 1.

The manipulated variables led to the formulation of the following hypotheses:
- Hypothesis 1: learners using an object filter (SOF, NOF, LOF) will have a higher knowledge gain (KG) than those using a room filter. We expect the specificity of the context information to influence the learning experience. In particular, we think that learning content filtered with more specific object context information, will lead to more specific interaction with the objects, and therefore will lead to better learning performance.
- Hypothesis 2: learners using a selection method that requires fewer actions (SRF, SOF, LORF) to access content will have a higher knowledge gain (KG) than those requiring more actions. We expect the interaction with the learning content in the mobile software will also influence the learner performance. A more efficient user interface that requires fewer actions from the learner, in our case the semi-automatic semacode-based (SRF, SOF) and automatic location-based (LORF) selection methods, will lead to more efficient information access and a better learner performance.

Participants

Thirty-five people (18 male, 17 female; *M* = 31.06 years, *SD* = 8.93) participated in this study. All participants were volunteers. Most of the participants spoke Dutch as

their native language (n = 26), however some spoke German (n = 6), Chinese/Cantonese (n = 1), Tamil (n = 1), and Spanish (n = 1). Only two participants stated they were to some extent acquainted with Hindi, the rest was not. Dutch pre-test and post-test questionnaires were given to those who spoke Dutch, while the other participants received a translated English version of the questionnaire (see Appendix A and B). Participants were randomly and evenly distributed over the seven treatments (see table 6.1).

Apparatus

Participants were equipped with an iPhone 3G device (http://www.apple.com/-iphone/) to access web-based language learning software optimised for these devices. The language learning software was a mobile phrase book for learning Hindi that uses contextual information to filter the learning content. The phrase book contained learning content consisting of a picture of an object, a textual representation of the Hindi word for the object, and an audio fragment for the word created by a native speaker. Moreover, the learner could view an enlarged version of the picture with a higher level of detail. For each of the treatments in table 6.1 another variation of the mobile language learning software was developed. The software was developed in PHP and the learning content was adapted to be rendered on small screens.

Figure 6.1 shows three screenshots from the language learning software for one of the variations (SRF) using a user-entered room number (zone) to filter a list of language content. At start-up, all content is displayed (left screenshot); the learners can scroll through the list and view detailed information for each object: an image (middle screenshot), text, and an audio representation of the word. When the learners enter a room they can filter the learning content by entering the room number (right screenshot); only the list of learning content for the room number entered is displayed.
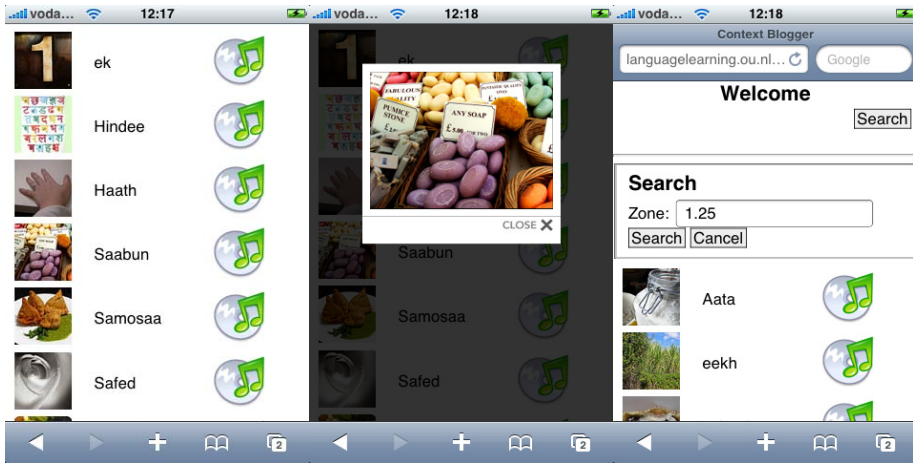
Figure 6.1: One variation of the language learning software using a room context, number‑based selection method (SRF) to filter the learning content

Procedure

The experimental procedure consisted of three parts: a pre-test phase, a learning phase, and a post-test phase. In the pre-test phase participants were randomly assigned to one of seven treatments. Furthermore, they were given a pre-test questionnaire, in which all participants were also given a treatment-specific textual instruction on how to use the software (see Appendix A for an example). Apart from the textual instruction the pre-test questionnaires were exactly the same. During the learning phase the participants were equipped with an iPhone 3G and a version of the software for the treatment they were assigned to. Just before the start of the learning phase, an extra verbal instruction was given to the participants on how to use the software. In the learning phase, the participants had to explore six rooms in the CELSTEC Medialab, all of which had a number of posters which each depicted an object. All participants were given exactly thirty minutes to learn as much of the Hindi vocabulary for the depicted objects as possible. The post-test phase comprised a post-test questionnaire testing the vocabulary learnt (see Appendix B), a usability evaluation measuring the hedonic and pragmatic quality of the software (Hassenzahl, Burmester, & Beu, 2001; Hassenzahl, Platz, Burmester, & Lehner, 2000) and an interview about the desirability of the software using the Microsoft Desirability Toolkit (Benedek & Miner, 2002). An audio recording was made of each interview using a laptop computer and Apple's Garageband software (http://www.apple.com/ilife/garageband/).

RESULTS

The results are treated separately by desirability, usability, and knowledge gain.

Desirability

The interview on the desirability of the software revealed that the software was overall rated as positive. Nevertheless, the participants listed some shortcomings and suggested a number of improvements and additions to current version of the software. First, most participants suggested to add a translation of the Hindi words in either Dutch or English. In addition, a search function was requested that made it easier to find language content on demand. Related to that, a lot of the participants recommended making the categories in the language content more explicit in the software. In general, the learners claimed that when the implicit categories in the learning content became clear to them, it helped them learn more efficiently. Especially, they thought the organisation of learning content into higher-level categories was necessary, and some even requested an option to organise the learning content into categories themselves. Some participants proposed more personalisation to the learning content, adapting the learning content in the software to their personal interests. Moreover, most participants requested an interaction history in which learning content previously accessed could be quickly found back. The history would serve as a way to repeat words efficiently; the repetition in some of the variations of the software was not straightforward and learners stressed its importance for learning. Another idea to improve the efficiency that was put forward was the possibility to access objects related to the object that was currently accessed. In addition to that, the learners would like to see related sentences for each object and language content in a sentence context. Last, the participants using the semacode-based approaches stated that the software was slow, and that the semacode tags were often not recognised. This led to frustration and less effective content access.

Usability

The usability was measured using a standardised usability evaluation that measured (1) the pragmatic quality (PQ), that describes how successful the users are reaching their goals using the software, (2) the hedonic quality – identity (HQ-I), which describes to what extent users identify themselves with the product, (3) the hedonic quality – stimulation (HQ-S), measures to what extent the users experience the software as innovative and stimulating, and (4) the attractiveness (ATT), describes a global quality value for the product. The mean values and standard deviations for the usability measure for each of the treatment groups are reported in table 6.2; a

usability measure is reported on a scale of -3 to 3, where a higher value corresponds to a better score.

Table 6.2
Mean values (*M*) and standard deviations (*SD*) for the usability measures (PQ, HQ-I, HQ-S, ATT) for each of the treatment groups

	Selection method							
	Semacode-based		Number-based		List-based		Location-based	
Context Filter	M	SD	M	SD	M	SD	M	SD
PQ								
Room Filter	1.11	.80	1.43	.50	1.20	.89	1.60	.85
Object Filter	1.17	.69	.97	.98	.96	1.11		
HQ-I								
Room Filter	.89	.80	.71	.97	.94	.94	.83	.94
Object Filter	.54	.77	.87	.65	.36	.59		
HQ-S								
Room Filter	1.31	.86	1.49	.43	1.43	.63	.60	.69
Object Filter	1.23	1.04	1.40	.92	.63	.48		
ATT								
Room Filter	1.83	.27	1.97	.45	1.80	.49	1.63	.44
Object Filter	1.49	.20	1.14	.19	1.03	.34		

On average the number-based treatments are valued highest in terms of usability (*M* = 1.25, *SD* = .34), while the list-based approaches are valued lowest (*M* = 1.04, *SD* = .31). Furthermore, the room-based treatments outperform the object-based treatments in all usability aspects (see figure 6.2). Overall the list-based object filter (LOF) was evaluated worst in terms of usability (*M* = .74, *SD* = .31): it was ranked lowest for PQ, HQ-I, and ATT. Conversely, the number-based room-filter (NRF) was evaluated best (*M* = 1.40, *SD* = .52): it ranked highest in HQ-S and ATT. Last, the location-based room filter (LORF) has the highest pragmatic quality PQ (*M* = 1.60, *SD* = .85).
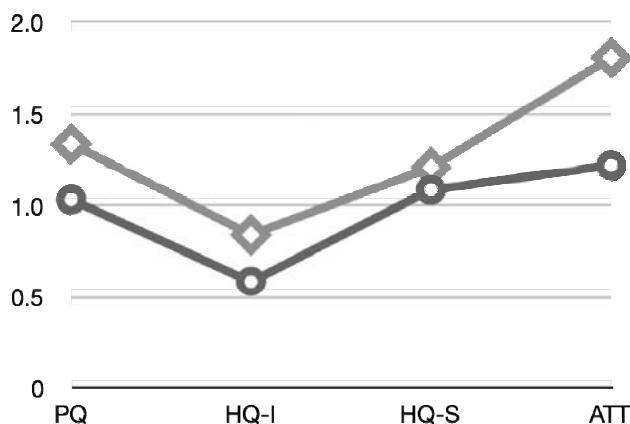
Figure 6.2: usability measures (PQ, HQ‑I, HQ‑S, ATT) for the room filter (diamonds) and object filter (circles) groups

As part of the usability the number of actions needed to access learning content was also considered. Table 6.3 lists the mean number of actions needed per room to access all the learning content available for that room; a lower number of actions is better, because it corresponds to a smaller burden on the learner to access all learning content. In this case, a more specific learning context requires a more specific filtering of the learning content; the object-based filter will deliver learning content for one object only, while the higher-level room filter delivers learning content for all of the objects available in the room. Therefore, to access learning content for a higher-level context, by using a lower-level object-based filter, more actions are required of the learner: after all, for each object an action has to be carried out to access the learning content. The location-based room filter required fewest actions to access all learning content, while the number-based object filter required most.

Table 6.3
Mean number of actions necessary per room for each of the treatment groups

Context Filter	Selection method			
	Semacode-based	Number-based	List-based	Location-based
Room Filter	2	3	2	1
Object Filter	37	55.5	37	

In general, across all treatments, the software was rated as technological and cautious on the negative side, and as manageable, inviting, and good on the positive side. Although all of the variations of the software were rated as very attractive, the

usability evaluation reported that there was still room for improvement in terms of usability and hedonic quality in all cases.

Knowledge Gain

The results show that the learner performance on the pre-test was not significantly affected by the treatment group, $F(6, 28) = .39$, *ns*. In addition, the self-evaluated abilities to learn languages and to learn languages quickly did not differ significantly for the treatment groups, $F(6, 28) = 0.6$, *ns* and $F(6, 28) = 1.03$, *ns* respectively.

For each of the participants the knowledge gain was calculated from the pre-test and post-test using Equation 6.1. Table 6.4 lists the mean knowledge gain and the standard deviation for each of the treatment groups, where a high knowledge gain corresponds to a better learner performance. It can be seen that the group using a semacode-based object filter (SOF) on average performed worse, while the group using a location-based room filter (LORF) performed best.

Table 6.4
Mean knowledge gain (*M*) and standard deviations (*SD*) for each of the treatment groups

	Selection method							
	Semacode-based		Number-based		List-based		Location-based	
Context Filter	M	SD	M	SD	M	SD	M	SD
Room Filter	.35	.24	.38	.20	.47	.04	.62	.13
Object Filter	.22	.12	.37	.14	.35	.18		

The results show that the knowledge gain was significantly affected by the treatment given to the participants, $F(6, 28) = 2.93$, $p < .05$, $r = 0.79$. Moreover, the effect of the context filter on knowledge gain was also significant, $F(1, 33) = 5.70$, $p < .05$, $r = 0.42$. Last, the knowledge gain was also significantly affected by the selection method, $F(3, 31) = 4.88$, $p < .05$, $r = 0.69$. Levene's tests for all of these comparisons turned out to be non-significant, supporting the assumption of homogeneity of variance.

Pair-wise t-tests with Bonferroni correction used as post hoc tests revealed a significant difference between the semacode-based object filter (SOF) treatment and the location-based room filter (LORF) treatment ($p < .05$). Moreover, the room-based context filter group differed significantly from the object-based ($p < .05$). Last, a significant difference was also found between semacode-based and location-based selection methods ($p < .05$). All other comparisons were non-significant.

DISCUSSION

The participants were randomly distributed over the treatment groups. Furthermore, the results show that all participants had similar scores on the pre-test, and self-evaluated their language abilities similarly. Therefore, it can be safely assumed that the participant's language expertise was evenly distributed over the treatment groups and any differences measured were caused by the experimental manipulations.

Hypothesis one is not supported by the results. Although a significant difference between the room filter and object filter approaches has been found, from the post hoc analysis and the mean knowledge gains reported in table 6.4, we can conclude that this is due to a significant difference between two treatment groups. More specifically, the difference in performance between the context filter groups can be traced back to the difference between the location-based room filter (LORF) treatment which performed best, and the semacode-based object filter (SOF) treatment which performed worst. Thus, more specific information about the learner context does not seem to lead to a higher knowledge gain on the vocabulary-learning task in this study. Rather, as all but one of the room filters perform better than the object filters, the opposite can be inferred: for the described vocabulary-learning task learners benefit from a more generic context filter, giving them an overview of the content present in the room.

Hypothesis two is only partially supported by the results. A significant difference has been reported between the semacode-based and location-based selection methods. According to our predictions though, both the location-based as the semacode-based groups, by the amount of effort required to access the information, would have to outperform the other groups for the hypothesis to hold. Thus, while the location-based treatment outperforms all other treatments, as we expected, the semacode-based approaches perform worse than expected.

The results become clearer if we look at the combination of the context filter and selection method. Table 6.3 presents the mean number of actions the learners needed to carry out to access all the learning content available in a room; hence, table 6.3 shows the combined effort needed in the authentic context and user interface to access all vocabulary in the room. It can be clearly seen that for the room filters the learners have to carry out fewer actions to access the learning content than those using an object filter. Apparently, this result is also reflected in the measured usability as the room-based filters outperformed the object-based filters (see figure 6.2). In addition, three of the room filter treatments have a higher knowledge gain than the object filter treatments. In particular, the location-based room filter (LORF)

required least actions of all the treatments, was rated highest on pragmatic quality (PQ) in the usability test (*M* = 1.60*, SD* = .85), and outperformed all other treatments in terms of knowledge gain. It can be concluded that learners using a treatment (NRF, LRF, LORF) that requires fewer actions in the authentic context and in the interaction with the mobile device will have a higher knowledge gain (KG); the semacode-based room filter (SRF) is the exception. Since the other context filters outperform the semacode-based filters in their class (= row), we expected another effect influencing the results. The desirability interviews with the participants made clear that the software did not detect the semacodes correctly all the time, and therefore the number of actions needed to access the learning content increased beyond that which was reported in table 6.3. In addition, this increased effort led to frustration with software for some participants, and therefore a lesser knowledge gain on the vocabulary task in this study. Had the semacode-based filters worked correctly, we would expect all room filters to have outperformed the object-based filters.

These results raise three questions. First, we expected a more specific object filter to lead to a more specific learning experience, and thus a higher knowledge gain. However, the results led to believe the opposite to be true: a more general room context led to higher learner performance. Obviously the vocabulary-learning task in the study did not benefit from more specific context information. Therefore, an interesting question that remains is when a more specific context filter does lead to a better learner performance and especially if there are differences in terms of learner transfer and retention in comparison with more general filters.

Second, the influence of the selection method on the learner performance is not entirely clear. While the group performing the fewest number of actions performed best, still the knowledge gain seemed quite resilient to the amount of actions performed: the number-based and list-based object filters did not perform significantly worse than the room filter treatments.

Third, it is important to consider to what extent the learner task directly influences the effectiveness and efficiency of the context filters. The learning task plays an important role in the cost of accessing learning content and the benefits that arise from it. The authenticity of the task might influence the impact of this cost/benefit balance; learners using the phrasebook in an explorative way in the real world might be satisfied with a higher cost because the benefit is also influenced by the authentic task at hand. Moreover, the benefit in authentic environments may arise from different causes than the vocabulary-learning task in this study. Thus, an important question is when this cost/benefit balance is optimal for learner performance. For the vocabulary-learning task presented in this study, a room filter was

more efficient because it gave more information in comparison to the actions needed by the learner. Besides that, the benefit of the learning tool for people with object-filter approaches did not outweigh the effort necessary. An interesting question is how to keep the cost/benefit balance similar for learners with different granularities of context filters: if more effort is required, the return value for this effort should be worthwhile. Especially, in shortly lived information access in a mobile scenario, the cost/benefit balance will influence the learner performance. Further research should find out the influence of the selection method and context filters on this balance.

The questions lead to several suggestions and recommendations for future research and future mobile learning applications. First, to be able to measure the effects on learning performance of the more specific object-based filters versus the room filters the cost and benefits of using those filters should be the same. If learners can access the same amount of learning content with a similar effort, the effects measured can be really attributed to the specificity of the context filter used. In this respect, the learners suggested a history of recently accessed learning content to simplify repetition of language content. Moreover, they thought that accessing objects in the same category as the one currently accessed would benefit their learning. Both suggestions will simplify the access of learning content (reduce the cost) and make it faster to learn more vocabulary (improve the benefit).

Second and related to that, it would be interesting to further investigate how context specificity influences learning. Does a more specific learning context result in a more specific, thus deeper learning experience and a better retention? And what situations would require which type of specificity? Moreover, how can results from a specific authentic learning context be transferred to a more general one? In that respect, an investigation into combinations of specific and more general learning contexts becomes worth considering.

Third, the effects of categories or semantic context in mobile language learning need to be looked at in more detail. Most learners indicated that they benefitted from the implicit categories that the objects in a room belonged to and would like to see these categories more explicitly presented in the user interface. The effects of further ordering the information on learner control, performance and satisfaction is another fascinating point to consider.

Last, the technology used in this study still had some problems. The participants assigned to semacode-based treatment reported that they often needed to scan the semacodes several times before they were detected. It would be interesting to see the results, if less effort for the semacode approaches was required. In addition, the

implementation of fully automatic object detection was not feasible at the moment of this study, and therefore left unconsidered. However, with recent developments in RFID technology it would also be possible to implement this eight scenario and compare it to the other comparisons in the experiment. Another promising opportunity that reduces the effort to access the learning content would be augmented reality: Hindi language content could be overlaid over a camera image of the objects and be instantly accessed by the learners, resulting in a range of new and interesting learning scenarios.

CHAPTER 7
The Effects of Mobile Learning in a Real-World Context on Learner Performance in Building Engineering

ABSTRACT

Fieldtrips provide a rich source of real-world stimuli that can be beneficial to learners in architecture, engineering, and construction. However, for a fieldtrip to be a lasting learning experience it has to be well prepared and integrated into the existing curriculum. This paper presents an evaluation of a mobile learning tool that aims at better integration of fieldtrips in a building engineering curriculum. Eighteen students participated in this study, and were randomly and evenly distributed over two treatment groups. The aim of the experiment was to investigate whether students participating in the mobile-device-supported fieldtrip would outperform students that remained in the classroom on a compulsory assignment. Results obtained after the evaluation of the assignments indicated that the mobile group had significantly higher final grades than the classroom group and, in particular, significant differences were found in identifying construction-related and contextual building aspects. On the other hand, it is also observed that fieldtrip students achieved a broader and more detailed focus of the subject, identifying more elements of the building under study. It is believed that the use of mobile learning tools in building engineering courses can contribute positively to the integration of fieldtrips in the curriculum, can extend learning outside classrooms, and improves students' learning and perception of buildings.

INTRODUCTION

Authentic learning scenarios can provide the learner with real-world stimuli that are not available in the classroom. Particularly, the applied sciences, like for example building engineering, can benefit from such scenarios. Fieldtrips form one of the most used scenarios to emerge the learner in authentic experiences. However, for a fieldtrip to be a lasting learning experience, it is important that it is well-prepared and integrated as part of the normal classroom curriculum. In this sense, a number of problems with integrating fieldtrips into the curriculum can be identified: (1) experiences may not be preserved to be accessed in the classroom, (2) support from information sources used in the classroom, are mostly not available on-the-spot, which might lead to missed learning opportunities, and (3) support by teachers or peers might not be readily available. The aforementioned problems can to a great extent be solved using information technologies in general, and mobile devices in particular. Mobile devices provide unique opportunities to support learning in authentic situations outside the classroom. The personal characteristics of these devices make it possible to reach learners almost anywhere and anytime. Next to the delivery of learning content in real-world settings, learners are also able to create a wide variety of multimedia content (text, pictures, audio, video) that can be used to

preserve learning opportunities encountered. Moreover, these inherently social devices enable the learner to reach their peers almost completely independent from their current context. The sensors present in most mobile devices can be used to acquire information about the learners' current situation, for example their location. This context information can help in tailoring the learning content to make it suitable for the situation. Already, a variety of location-based systems have been considered in the mobile learning literature. In this paper, we will present another mobile learning tool to support building engineering students in fieldtrips.

BACKGROUND AND RESEARCH MOTIVATION

There are a number of areas of higher education in which it is essential that students have access to visual examples, and ultimately, real-world practice, in order to fully appreciate the implications of the theory and classroom-based learning. Many subjects in the construction field, including architecture and a range of engineering subjects, fall within this category (Wilkins & Barrett, 2000). The instruction methods used in the majority of construction, engineering, and management curricula rely on traditional methods such as exposing students to applied science courses (Moonseo, Swee, & Yashada, 2003). However, most often enough, the theoretical concepts learnt with these traditional teaching methods are not effective enough in providing students with all the knowledge necessary in the construction world. In search for novel methodologies to confront this challenge, building educators have become aware of the high interest in new technologies, adding computer-based media in their courses. A variety of approaches can be found in the literature (Wilkins & Barrett, 2000; MACE portal, 2009; Virtual Building & Construction Environment, 2000; Martini, 1996) but they are mostly based on virtual environments of different degrees of immersion. Then again, as stressed by Spicer and Stratford (2001), these virtual environments cannot replace traditional fieldtrips. Students need to complete their building courses by participating in fieldtrips and in real-life simulations improving and motivating them to learn by doing, learn by practicing, and learn by observing. The students benefit by actually seeing the principles applied in real buildings and construction sites. Various studies have indicated the necessity and importance of authentic activities in which students can work with problems from the real world (Chu, Hwang, & Tsai, 2010; Hwang, Tsai, & Yang, 2008).

Fieldtrips are an interesting educational instrument to confront students with knowledge in a real-world context. They provide a form of learning that can encourage learners to actively participate and engage with the learning content. According to Willis, Hölscher, Wilbertz, and Li (2009) an active engagement in the environment,

stimulates and motivates to learn and results in knowledge about the space in which the learner is moving. An attitudinal study carried out for fieldtrips in geological education by Orion and Hofstein (1991) confirmed this positive attitude of students to learning on a fieldtrip. What is more, the rich real-world context of fieldtrips presents the learner with a variety of stimuli. As such, fieldtrips are an important source of context-dependent knowledge, and provide multiple representations to learning content, important for learning (Spiro, Coulson, Feltovich, & Anderson, 1988). In addition, fieldtrips also form the authentic context that normally involves the use of context-specific knowledge, which according to Wenger and Lave (1991) is important for learning to be effective. More specifically, the educational effectiveness of fieldtrips has been investigated in several studies that marked them as beneficial for learning (MacKenzie & White, 1982; Rosenthal, 1968). In this respect, Orion (1993) distinguishes two groups of concepts that can be successfully taught on fieldtrips: (1) concepts derived from sensori-motor experiences, and (2) phenoma-related concepts that are used as concrete examples for learning in the classroom. Related to that, Dillon et al. (2006) state that fieldtrips, if properly planned, carried out, and followed up, are a valuable addition to the classroom experience in further developing knowledge and skills.

Particularly, the integration of fieldtrips into an existing curriculum is an important point to consider for the effectiveness of fieldtrips. Orion (1993) states that the concrete activities during a fieldtrip could provide a basis for meaningful learning and fieldtrips should be integrated as a particular unit in the curriculum. To facilitate a better integration, Orion (1993) presents a model to plan and integrate a fieldtrip into a curriculum. First, Orion states that the learner should be actively involved in the activities that are part of the fieldtrip, addressing specific activities that cannot be taught in the classroom. Second, assignments should be used to guide the learner in the field and the learning experiences encountered during the fieldtrip should be properly followed up in the classroom; the experiences, if well documented, could be laid out and interpreted more specifically in the classroom. Third, the activities during the fieldtrip benefit if the theory involved has already been dealt with in the curriculum as preparation. In this respect, the availability of theoretical information in-situ can also be beneficial for learning. Fourth, the fieldtrip should be integrated into the curriculum, because the concrete activities could provide a basis for further learning. Last, the authors expect learners could benefit from peer support during the fieldtrip.

Moonseo, Swee, and Yashada (2003) stated that information technologies for educational purposes have the potential to act as excellent tools to complement construction education. Information technology could help improving the learning benefits from fieldtrips for construction education by supporting the learner on a field-

trip and by facilitating a better integration of field-trip experiences into classroom education and the curriculum. More specifically, three problems inhibiting learning could be addressed with information technology. First, the learning experiences on the fieldtrip may not be preserved to be accessed in the classroom. By supporting the learner to create learning content in the field, that can later be accessed, the learning experiences can be carried across different learning contexts. Second, the theory and information sources used in the classroom are mostly not available on the spot; learners can however benefit from just-in-time learning information offered during task-performance (Kester, 2003; Kester, Kirschner, & Van Merriënboer, 2006). Third, learning support by teachers or peers may not be readily available. Learning performance may increase by providing the learner with peer-generated learning content in an authentic learning context, enriched with tags and comments. Above all, mobile devices provide unprecedented opportunities to implement new learning scenarios by integrating real-world learning environments and the resources of the digital world (Ruchter, Klar, & Geiger, 2010; Rogers, Connelly, Hazlewood, & Tedesco, 2010; Chu, Hwang, & Tsai, 2010). Thus, the use of mobile devices can help to address the aforementioned problems, can support the learner during fieldtrips, and could be beneficial for building engineering scenarios in authentic settings.

Already a variety of studies have focused on supporting fieldtrips with mobile devices. The research can be classified in studies where mobile devices are used for (1) learning content delivery, (2) content creation, (3) communication between peers, and (4) learning across contexts, during a fieldtrip. In *the first category*, Mitchell & Race (2005) present the uLearn system, which allows pupils to gather information about the animals in a zoo, using their mobile devices. During the fieldtrip, pupils could access the information about an animal by scanning a visual code near the enclosure. The Environmental Detectives framework developed by Klopfer, Squire, & Jenkins (2002) is another example that simulated an environmental disaster students had to investigate. The mobile devices were used to overlay the simulated disaster over a real-world scenario, and students could take simulated air and water readings to investigate the disaster. *The second category*, includes examples that focus on learning content creation in authentic learning environments. Arnedillo Sánchez (2008) presented a mobile digital narrative tool with which students could record video and audio in real-world locations that could be edited by their peers, resulting in a social video production process. Moreover, PhotoStudy (Joseph, Binsted, & Suthers, 2005) aimed at the collaborative creation of picture flashcards for vocabulary learning, using a mobile phone camera. Another example was given by Cavus and Uzunboylub (2009), who investigated the effect of mobile devices on students' critical thinking skills. They focused on the usefulness of mobile telephones in increasing students' awareness of environmental concerns. In this study,

students used mobile devices to access, discover, discuss, and share environmental concerns via multimedia messaging services (MMS), short message service (SMS), electronic email, or MSN Messenger. Students also created new content, taking pictures of environmental problems with the camera of the mobile device. *The third category* provides a set of studies that use mobile devices to improve communication between users during fieldtrips. RAFT (Bergin et al., 2007) focused on a cross-context communication between students in the field and students in the classroom, bridging the gap between the classroom and an authentic learning context. In addition, with the LOCH system (Paredes et al., 2005) a teacher in the classroom could support second language learners in an authentic real-world scenario. Last, *the fourth category*, encompasses studies in which mobile devices have been used to achieve learning across contexts. MyArtSpace (Sharples, Lonsdale, Meek, Rudman, & Vavoula, 2007) investigated a better integration of museum visits into classroom work, by using mobile devices to collect multimedia content in one context, the museum, that could later be accessed in another, the classroom. In addition, Rogers et al. (2010) present a mobile learning application, LillyPad, used by teams to make sense of their ongoing observations, when measuring the effects of different planting methods for an environmental restoration site. The mobile learning tool described here will integrate the four categories of mobile support for fieldtrips to assist students in the field of building engineering.

While the mobile learning literature provides a wide range of museum and outdoor scenarios, the application of mobile devices to support fieldtrips in building engineering has been largely unconsidered so far. More specifically, few studies have investigated the educational outcomes of mobile learning (Uzunboylu, Cavus, & Ercag, 2009; Cavus & Uzunboylub, 2009). The research presented in this paper aims to address part of the gap by presenting an evaluation of the educational effects of mobile technology supporting fieldtrips in building engineering. While much of the related work focuses on technical feasibility and general user satisfaction, this paper will present a fieldtrip experiment that additionally investigates the impact of mobile devices on learning performance in the field of building engineering education. More specifically, the effect of fieldtrips on various parts of assignment performance is investigated with a rubric containing several categories of aspects important for building engineering. To assist learners to integrate the real-world experiences into classroom assignments, a mobile learning application (ContextBlogger mobile client) and a web portal (ContextBlogger portal) have been specifically designed. Engineering students from a course of the Construction Engineering program of the Technical University of Catalonia (Spain) participated in the study. Two groups of students were compared on their performance on a compulsory assignment aimed at identifying the main construction characteristics of one particular building. The classroom group, gathered information needed to complete the assignment using

various digital and non-digital sources, whereas the fieldtrip group carried out an additional fieldtrip to gather annotated photo material with smart phones. As the group performing the fieldtrip was confronted with rich real-world stimuli not available in other forms of learning material, it is expected that their performance on the assignments will be better than the classroom group. To sum up, in this paper, we not only evaluate mobile learning from a technological point of view (desirability, usability) but also from an educational perspective (effectiveness), adapting the evaluation framework proposed by Sharples (2009). The results of the evaluation with this framework will be presented in this paper.

METHOD

Design

The main objective of the experiment was to test the improvement that fieldtrips supported by mobile devices produce in student achievement in the field of building engineering education. The study used a between-groups design with one independent variable and four dependent variables. The independent variable had two levels (fieldtrip, no fieldtrip) and manipulated whether students participated in a mobile-device-supported fieldtrip. The dependent variables were measured with a rubric that was used to evaluate a post-test assignment that was given to all participants.

Assignment objectives and evaluation
Each participant was given a post-test assignment in which they were asked to individually develop an analysis of a particular building. The final objective of the assignment was to put into practice all the building knowledge acquired during previous lessons in the course. Students had to identify different characteristics and aspects of the building such as:

- *general aspects* (name of the architect, construction date, etcetera),
- *construction-related aspects* (structural solution, construction materials, etcetera)
- *contextual aspects* (location, urban design, similar buildings, etcetera).

The list of these expected aspects was not provided to the students, although some examples were exposed in the classroom to guide the students at the beginning of the assignment. Each assignment should be delivered in essay form, containing both textual information and graphical information. The textual information should include the description of the identified characteristics of the building, and the graphical information (such as pictures, drawings, sketches, etcetera) should con-

tribute to the understanding of the text. The students could use graphical objects already available from different sources such as books or the Internet, or create them themselves. The participants had 15 days to finish the assignments.

The post-test assignments were evaluated using a rubric designed for this purpose. Stevens and Levi (2005) describe a rubric as a scoring tool that lays out the specific expectations for an assignment. Rubrics divide an assignment into its component parts and objectives, and provide a detailed description of what constitute acceptable and unacceptable levels of performance for each part. Rubrics are composed of four basic parts: a task description (assignment), a rating scale that measures the performance level on any given task, the dimensions of the assignment to be evaluated, and the descriptions of what constitutes each level of performance. The rubric designed for the evaluation of the post-test assignment consists of (also see Appendix C):

- *The task description*: "each student will individually write an essay aimed at the identification of the main aspects and characteristics of a particular building. The assignment should include appropriate textual information and graphical information."
- *A rating scale*: a three level scale has been defined (0–2), where 2 has been assigned to the best performance and 0 to the worst or non-existent performance.
- *Dimensions*: 29 dimensions have been defined, classified in 2 categories:
  - Expected aspects (25): aspects that should be included in the assignment for a good grade. These aspects, at the same time, are classified in three sub-categories: general aspects, construction-related aspects, and contextual aspects.
  - Media information (4): dimensions to evaluate the variety and the level of detail of the provided graphical information.
- *Descriptions*: three descriptions have been specified for each dimension. These descriptions are defined separately for the evaluation of each dimension, but in general terms:
  - Level 2 (2 score): the aspect is correctly identified and described.
  - Level 1 (1 score): the aspect is only correctly identified.
  - Level 0 (0 score): the aspect is not identified or it is not correctly identified.

The rubric was designed based on other rubrics used in the evaluation of assignments of other building engineering courses. It contains the main aspects needed to perform a complete analysis of an existing building from a construction point of view; from the general information such as the name, the architect, and basic project data, to the list of elements that are part of a building, such as the structure, the walls, the roof, etcetera. The students were not provided with the rubric, and

therefore did not know about its existence. The rubric includes all the aspects exposed during the course and it could be used to evaluate any kind of assignment similar to the one proposed here, carried out with or without a fieldtrip. It should be pointed out that, four dimensions related to the media information were added to the rubric, although they were not used to obtain the assignment's final grade. They were defined for the calculation of the value of some of the dependent variables related to the variety and quality of the information provided. Thus, the rubric described here is used to obtain the participants' assignments final grade, as well as the value of the dependent variables defined, to understand the differences in the performance of the fieldtrip group and the classroom group.

The Independent variable
The independent variable was defined to differentiate whether students went on a mobile-device-supported fieldtrip. The levels of the independent variable were specified as follows:

- *Fieldtrip, with mobile client*; *the experimental condition*, in which the participants used the developed mobile client application during a fieldtrip, could use the ContextBlogger portal, and various sources of information, non-digital (books) as well as digital (the Internet), to gather information about buildings and construction in the classroom and at home.

- *No fieldtrip, no mobile client; the control condition*, in which the participants could use various sources of information, non-digital (books) as well as digital (the Internet), to gather information about buildings and construction in the classroom and at home. This group of students did not go out on a fieldtrip.

Dependent variables
Four dependent variables were defined to measure the differences in performance between the fieldtrip group and the classroom group. Their values were obtained from the rubric evaluation. The four dependent variables are described below.

The number of correctly identified aspects (NCIA): the number of correctly identified aspects from the expected aspects category (EA). The variable evaluates the availability (or absence) of information related to the expected aspects but does not consider the detail of that information. The number of correctly indentified aspects can then be calculated with the following formula:

$$NCIA = \Sigma \ (Score_{EAi} > 0), \ NCIA \in [0, 25], \ i \in [1, 25] \qquad (7.1)$$

The expected aspects category was subdivided according to the three subcategories identified earlier: the general aspects (GA), the construction-related aspects (CA), and the contextual aspects (TA). Thus, three sub-variables can be defined for the

number of correctly identified aspects. First, the number of correctly identified general aspects:

$$NCIAgen = \Sigma\ (Score_{GAi} > 0),\ NCIAgen \in [0, 9],\ i \in [1, 9] \qquad (7.1.1)$$

Second, the number of correctly identified construction-related aspects:

$$NCIAcons = \Sigma\ (Score_{CAi} > 0),\ NCIAcons \in [0, 12],\ i \in [1, 12] \qquad (7.1.2)$$

And third, the number of correctly identified contextual aspects:

$$NCIAcont = \Sigma\ (Score_{TAi} > 0),\ NCIAcont \in [0, 4],\ i \in [1, 4] \qquad (7.1.3)$$

The level of detail of the information provided (LDI): while the previous measures defined the number of correctly identified aspects of a building, this dependent variable measures the level of detail for each of those aspects. The level of detail of the information provided is evaluated with the scale and descriptions of the rubric, which defines three levels of performance, from a high level of performance (Level 2) to a nonexistent performance (Level 0). The level of detail of the information provided will be calculated from the addition of the separate performance levels obtained for each aspect in the expected aspects category. The level of detail of information provided for all expected aspects together can then be calculated by the following formula:

$$LDI = \Sigma\ (Performance_{EAi}),\ LDI \in [0,50],\ i \in [1, 25] \qquad (7.2)$$

Again, considering the expected aspects subcategories, three sub-variables are defined. First, the level of detail of the general aspects:

$$LDIgen = \Sigma\ (Performance_{GAi}),\ LDIgen \in [0,18],\ i \in [1, 9] \qquad (7.2.1)$$

Second, the level of detail of the construction-related aspects:

$$LDIcons = \Sigma\ (Performance_{CAi}),\ LDIcons \in [0,24],\ i \in [1, 12] \qquad (7.2.2)$$

Third, the level of detail of the contextual aspects:

$$LDIcont = \Sigma\ (Performance_{TAi}),\ LDIcont \in [0,8],\ i \in [1, 4] \qquad (7.2.3)$$

The variety of the provided graphical information (VGI): the variety and the level of detail of the provided graphical information have also been evaluated using the

rubric. This information can be obtained by counting the number of photographs, drawings, and schemas and analysing their level of detail. The variety of the provided graphical information can then be calculated by the following formula:

$$VGI = \Sigma\ (Score_{Mi}),\ VGI \in [0,8\ ]\ ],\ i \in [1,\ 4] \qquad (7.3)$$

Related to this variable, two sub-variables are also defined: the number of photographs (NP), and the level of detail of the photographs (LDP). These sub-variables can then be calculated by the following formulas:

$$NP = \Sigma\ (photographs\ included\ in\ the\ assignment),\ NP \in [0,\ \infty\} \qquad (7.3.1)$$

$$LDP = Score\ obtained\ in\ the\ level\ of\ detail\ of\ the\ photographs$$
$$category,\ LDP \in [0,2] \qquad (7.3.2)$$

The final grade for the assignment (FG): the final score obtained for the whole assignment. The final grade is comprised of all separate scores in the expected aspects category. The final grade is calculated by the following formula:

$$FG = \Sigma\ (Score_{EAi}),\ FG \in [0,\ 50],\ i \in [1,\ 25] \qquad (7.4)$$

Hypotheses

The dependent variables in the rubric are used to compare the fieldtrip group and the classroom groups on several aspects. A number of expectations can be listed for the two treatment groups. Because of the richness of the authentic fieldtrip environment, we expect the fieldtrip group to identify more aspects, especially construction-related and contextual aspects, because they will be aware of more characteristics of the real building during the fieldtrip, which they will probably include in their assignments. On the contrary, the classroom group is expected to only identify those general aspects easily found on the Internet. For the same reason, we predict the fieldtrip group to identify each of the aspects in a greater level of detail than the classroom group. In addition, we expect to see the information gathered in the real world back in the assignments. Especially, we expect to see more photographs with a better level of detail, and a higher number of images per identified aspect, as the mobile tool offers a way to capture multiple perspectives on real-world objects. Last, we also expect the students in the fieldtrip group to be better motivated. Thus, we expect a better performance of the learners using the mobile tools in general. This can be summarised in the following hypotheses for this study:

- Hypothesis 1: the fieldtrip group will obtain a higher final grade for the assignment than the classroom group.
- Hypothesis 2: the fieldtrip group will identify more expected aspects correctly than the classroom group, particularly construction-related aspects and contextual aspects.
- Hypothesis 3: the fieldtrip group will include a greater level of detail for each of the aspects in the assignments than the classroom group.
- Hypothesis 4: the fieldtrip group will provide a greater variety of information than the classroom group. Especially, the number of photographs and their level of detail will be higher.

Participants

Eighteen students (10 male, 8 female; mean age = 21.06 years, *SD* = 0.80) participated in this study. These eighteen students were evenly split up in two different groups: the fieldtrip group (5 male, 4 female; mean age = 21.22 years, *SD* = 0.83) and classroom group (5 male, 4 female; mean age = 20.89 years, *SD* = 0.78). All participants were engineering students at the Technical University of Catalonia (Spain). The entire group was enrolled in the Fundamentals about Building Design course, which belongs to the Construction Engineering program. The main objectives of the course are to (1) provide basic knowledge on construction elements, materials, systems and techniques, (2) to identify the main aspects to consider in the building design process, and to (3) provide basic knowledge to represent the three-dimensionality of a building dealing primarily with drawings and models. Considering that the students enrolled in this course could be in different stages of the degree, special effort was made to assure that all participants had a similar level of knowledge in construction field; they were selected taking into account that they approximately took the same courses of the building engineering specialty of the Industrial Engineering course. Once the potential participants were identified, they were randomly and evenly distributed over the two conditions. None of the participants had any prior experience with neither the ContextBlogger mobile client software, nor the web-portal.

Apparatus

A web-based system was designed and built to support the participants during the fieldtrip. The system architecture is composed of two different systems:
- The *ContextBlogger mobile client*, the mobile application that the fieldtrip group uses to create and annotate geo-tagged pictures during the fieldtrip. It runs on the students' mobile devices.

- The *ContextBlogger web portal*, a web portal where all the pictures taken with the ContextBlogger mobile client are stored and shared by the users.

The *ContextBlogger mobile client* was developed with the .NET mobile framework and specifically designed for the HTC Touch Diamond mobile devices used in the experiment. The mobile devices ran Windows Mobile 6.0, and the software was implemented using the functionalities offered by this platform. The mobile client implements different functionalities to: (1) create new content by taking geo-tagged pictures of real-world objects, (2) enrich content by annotating tags and comments to the already existing pictures, and (3) to share content with other users. Figure 7.1 shows several screenshots of the mobile client. The first screenshot (Figure 7.1a) shows a list of nearby real-world objects that were already created by other users of the mobile client. By tapping the "Add object" button on the top, the user can create a new object tagged with the current geo-location. Alternatively, the learner can select one of the existing real-world objects in the list to display its photographs (see Figure 7.1b). At this point, the user can either create a new photograph by tapping the "Add Photo" button, or select one of the photographs to reveal a detailed view of a photograph. The detailed view (see Figure 7.1c) shows a larger version of the selected photograph and the tags that were added to identify specific subparts of the photograph. The learner can add a new tag by tapping the "Add Tag" button and specifying a tag name, description, and location. Additionally, the learner can select a tag to view detailed information about it, like its name, and the comments given for this tag (see Figure 7.1d). Furthermore, additional comments can be added to a tag by using the "Add Comment" button. The ContextBlogger mobile client requires an Internet connection for the photographs to be uploaded to the web portal. Moreover, the mobile client also requires an active GPS lock to tag the photographs with geo-location information. And obviously, it needs the mobile device to be equipped with an integrated camera to take the pictures. Users need to have an account (user name and password) to log into the mobile client. An account can be created using the ContextBlogger web portal and it is used for both systems.

Figure 7.1: Mobile client screenshots: (a) list of nearby existing geo-tagged real-world objects; (b) photographs for one real-world object; (c) detailed view of a tagged photograph; (d) tag details (in Catalan)

The *ContextBlogger web portal* is a web front-end developed in PHP and accessible through the Internet using any computer with a web browser. It is designed to enable the users to: (1) view all real-world objects and associated photographs that were created using the ContextBlogger mobile client. Information related to the pictures is also available (tags, geo-location and comments), (2) add comments and rate the pictures (it is necessary to be logged in), and (3) download the pictures to a personal computer. Figure 7.2 shows several screenshots of the web-portal. Users can access the real-world objects created last under the "Home" link (see Figure 7.2a). Furthermore, the learners can search the available real-world objects using

the search box on the left. Clicking the picture of a real-world object in the home page (or the link stating the number of photographs below), reveals a detailed view of the real-world object with a Google Map (http://maps.google.com) showing its location and the photographs created for this object (see Figure 7.2b). In the detailed view of a photograph the tags for that photograph can be seen, and when logged in, the learners can create comments and rate the available photographs (see Figure 7.2c). Moreover, users have a private page where all the pictures they have taken or tagged, as well as the list of tags they have added, are available. Thus, not only the user's own pictures are available in one quick glance, but also the interesting pictures taken by other users that he or she has tagged (see Figure 7.2d). During the experiment, each student was provided with a login name and a password, so that they could access both the mobile client and the web application.
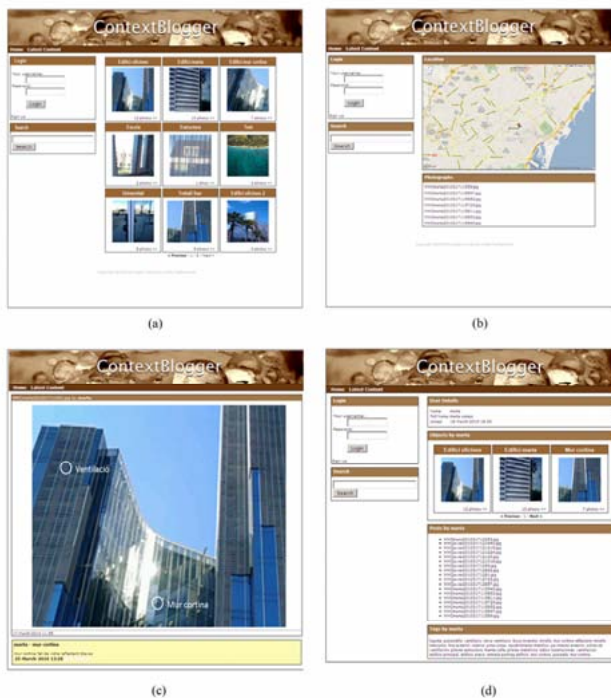
Figure 7.2: Web portal screenshots: (a) homepage with a list of real-world objects; (b) detail page for one real-world object and its geo-location; (c) detail page of one tagged picture; (d) user's personal page

Both the ContextBlogger mobile client and web portal were available for the field-trip group during the fieldtrip and the period of time assigned to perform the assignment. In addition, the participants in both treatment groups (fieldtrip and class-

room) could use a wide variety of information sources, ranging from digital sources on the Internet to non-digital resources like books.

Procedure

The experiment was designed to have four different stages: introduction, gathering of information, completion, and evaluation (see figure 7.3). The first stage, the introduction, lasted four weeks and was aimed at providing the students with basic knowledge of Building Design, including a building's constructive elements, the main constructive methods used to build a building, as well as the main materials used in construction. During this stage students were attending theory lectures in the classroom. The evaluation of these concepts learnt in the first part of the course was twofold: on the one hand, it was planned to be evaluated with some questions in the final exam, and by an individual assignment given to the students at the end of the course on the other. The individual assignment was compulsory for all the students. Therefore, during this stage of the experiment, the objectives, the expected results, and the deadline of the assignment were also described. Then, the eighteen students were randomly and evenly distributed over the two groups: the fieldtrip group and the classroom group.

The second stage was aimed at gathering all the information needed to complete the assignments. The classroom group started working on the assignment in the classroom, searching and gathering information via the Internet. In the mean time, the fieldtrip group was informed about the fieldtrip, the use of the ContextBlogger mobile client software, and the web portal. After the brief explanation, they also started gathering information in the classroom. From this initial session on, the collection of information was carried on by both groups at home. Also during this stage, and one week after the assignments were given, the fieldtrip group went on the fieldtrip and visited the particular building, the object of the assignment. The students were provided with a HTC Touch Diamond mobile phone and the login data to access the mobile client and the web portal. The ContextBlogger mobile client software had already been installed on all devices. The lecturer gave the students a short introduction to the mobile software. Then, each student had about 20 minutes to individually explore the building and its surroundings. During this period of time they could use the software to take pictures and add tags or comments; annotating information that they could use later in the assignment. They could also enrich other students' pictures with tags and comments to share knowledge and experiences. On the one hand, the classroom group gathered all the needed information from the Internet and other digital and non-digital resources. On the other hand, the fieldtrip group had also the opportunity to collect in-situ information

during the fieldtrip to complete the information obtained from the Internet and other types of resources.

Once students had collected most of the content material, they started the completion of the assignments. This part of the assignment was also done at home. The document structure was not predefined, and thus students were free to add any interesting content they had found about the building and its elements. The fieldtrip students could also extend their assignments with pictures and observations obtained during the fieldtrip; all available at the ContextBlogger web portal. Both groups had fifteen days to complete second and third stages, the gathering of information and the completion of assignments. After this, all the assignments were collected by the lecturer to be later evaluated.

The last stage was aimed at evaluating not only students' assignments but also the ContextBlogger mobile learning tool. First, the fieldtrip students were asked to answer a couple of online tests aimed at capturing the user's opinion in terms of the desirability (Benedek & Miner, 2002) and the usability of the software (Hassenzahl, Burmester, & Beu, 2001; Hassenzahl, Platz, Burmester, & Lehner, 2000). Second, assignments were evaluated by an evaluator blind to the experiment conditions. A rubric was provided to the evaluator to guide her across the evaluation process. All the results were collected and analysed afterwards. Figure 7.3 describes the experiment procedure for both treatment groups.
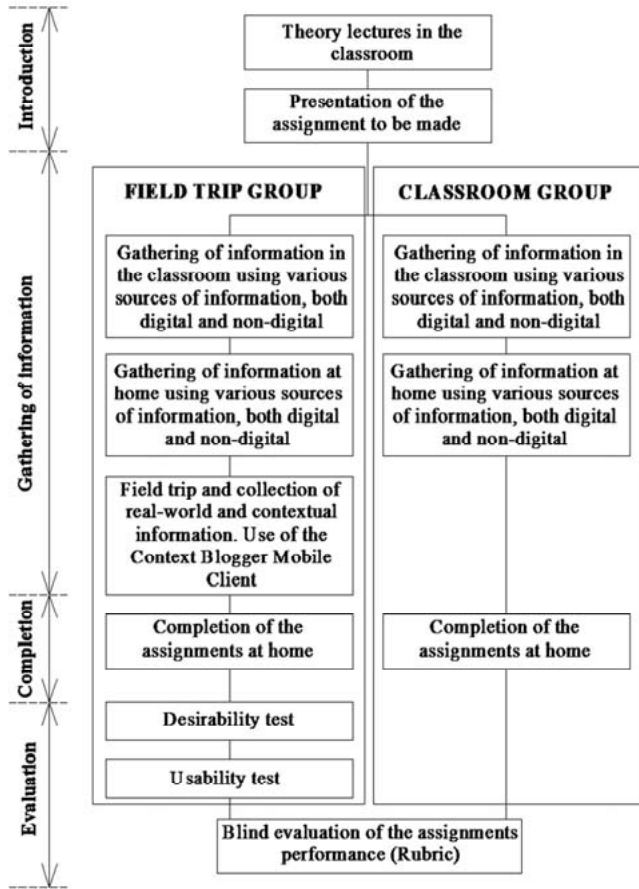
Figure 7.3: Experimental procedure

RESULTS

In this section, outcome data collected from each group is presented. The results of the software desirability test, the software usability test, and the assignments are considered separately below.

Software Desirability

The desirability results revealed an overall positive attitude of the students towards the developed ContextBlogger software, both the mobile client and the web portal. The software was rated as easy to use, attractive, and intuitive, as creative and innovative, as well as entertaining and useful. Users were especially positive about

the mobile client, while the web portal could still be improved. Almost all of the negative terms in the desirability test were related to the web portal. The web portal was rated as unattractive and unrefined, as well as annoying, confusing, and time-consuming. Especially these last comments referred to the organisation of the uploaded photographs for each real-world object; a proper preview of the photographs was missing and users could only access their photographs via a URL containing the filenames. This made it hard to find the uploaded photographs and difficult to see which photos had already been accessed. Conversely, the students were especially positive about the social network aspects of the software and identified it as being connected. The social aspects enabled them to share their content with others, bring forward their "own point of view about a place within the community", and enabled a sense of community: "it is amazing the interconnection between people who had already been there". Furthermore, watching photographs created by others sparked their creativity and curiosity. Students also hinted at the usefulness of being able to access the created photographs everywhere; one student stated that she would even use the tool "every time I found something interesting", while another student thought it an interesting tool to learn about places when travelling; both comments reflect a more personal and informal use of the software for learning. Last, the students explicitly identified the tool as helpful to support their learning: "I think it can be an excellent tool for learning" and "the system makes the student more comfortable with the studies and produces more interest in the subject".

Software Usability

The usability of the developed ContextBlogger software was measured using a standardised usability evaluation that measured (1) the pragmatic quality (PQ), that describes how successful the users are reaching their goals using the software, (2) the hedonic quality – identity (HQ-I), which describes to what extent users identify themselves with the product, (3) the hedonic quality – stimulation (HQ-S), which measures to what extent the users experience the software as innovative and stimulating, and (4) the attractiveness (ATT), which describes a global quality value for the product. The mean values for each of the usability aspects are reported in figure 7.4. The usability measure is reported on a scale of -3 to 3, where a higher value corresponds to a better score.
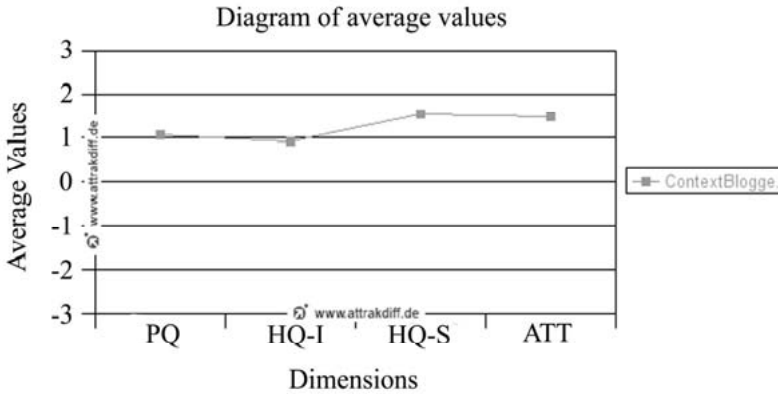
Figure 7.4: Mean values for each of the usability aspects (PQ, HQ-I, HQ-S, ATT)

Figure 7.4 shows that the software has average PQ and HQ-I values, while the HQ-S and ATT values are above average. The average PQ value indicates that there is still room to improve the software in terms of usability. Likewise, the average HQ-I value suggests that the software should be improved, should the user be bound more strongly to the software. On the contrary, the above average HQ-S value shows that in terms of stimulation the software is classified as optimal. Hence, the users indicated that the software stimulates them, awakes curiosity, and motivates them. The above average value of ATT implies the user's overall impression of the product was very attractive. Moreover, the users had quite similar opinions about the software, as the small confidence intervals reported in the usability evaluation indicated.

Learning Effectiveness

The data used to evaluate the differences in learning performance between the two groups was obtained from the rubric used in the evaluation of the assignments.

Final grade for the assignment (FG)
Figure 7.5 gives a box plot of the students' final mark for the assignment. As can be observed, participants in the mobile group had a significant higher final grade (M_{FG} = 36.89, SE_{FG} = .68) than participants in the classroom group (M_{FG} = 30.33, SE_{FG} = 1.12), $t(15.84) = 5.02$, $p < 0.01$, $r = .87$.
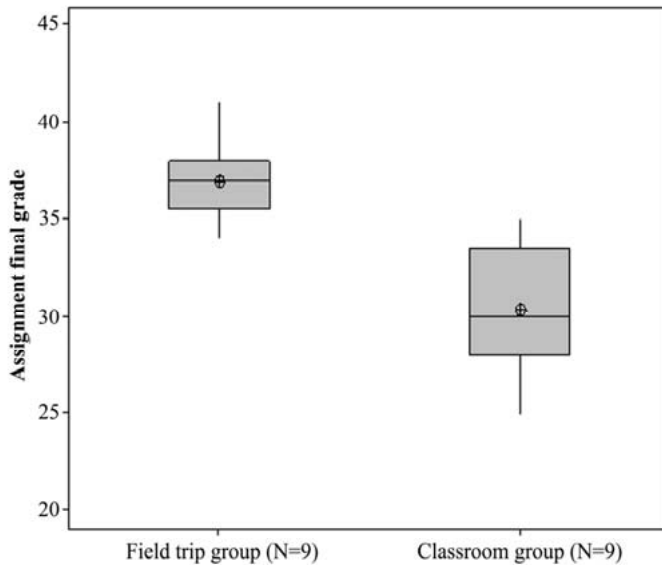
Figure 7.5: Boxplot of the assignment final grade for the two treatment groups

Next to the final grade calculated from the rubric, several dependent variables were specified to analyse the between-groups differences in more detail, these will be considered in separate subsections.

Number of correctly identified aspects
The mobile group (M_{NCIA} = 21.56, SE_{NCIA} = .41) identified significantly more aspects correctly than the classroom group (M_{NCIA} = 17.78, SE_{NCIA} = .57), $t(14.54)$ = 5.36, $p <$ .001, r = .81. The number of correctly identified aspects can be split up in three sub-variables. First, the number of correctly identified general aspects does not signifi-cantly differ between the mobile group ($M_{NCIAgen}$ = 7.89, $SE_{NCIAgen}$ = .26) and the classroom group ($M_{NCIAgen}$ = 8.22, $SE_{NCIAgen}$ = .22), $t(15.61)$ = -0.97, *ns*, r = .24. Second, the mobile group ($M_{NCIAcons}$ = 10.11, $SE_{NCIAcons}$ = .35) outperformed the classroom group ($M_{NCIAcons}$ = 7.67, $SE_{NCIAcons}$ = .62) on the number of correctly identified con-struction-related aspects, $t(12.61)$ = 3.42, $p <$ .01, r = .69. Third, there was a signifi-cant difference between the number of contextual aspects correctly identified by the mobile group ($M_{NCIAcont}$ = 3.56, $SE_{NCIAcont}$ = .18) and the classroom group ($M_{NCIAcont}$ = 1.89, $SE_{NCIAcont}$ = .39), $t(11.14)$ = 3.91, $p <$ .01, r = .76.

Level of detail of the information provided
Next to the number of correctly identified aspects, the level of detail provided for the aspects was also considered. In general, the mobile group (M_{LDI} = 36.89, SE_{LDI} = .68) provided a significantly higher level of detail for all of the aspects than the

classroom group (M_{LDI} = 29.89, SE_{LDI} = 1.20), t(12.64) = 5.10, p < .001, r = .82. The level of detail provided can again be divided in three subvariables identifying the level of detail for the general aspects, the construction-related aspects, and the contextual aspects. There was no significant difference in the level of detail provided for the general aspects between the mobile group (M_{LDIgen} = 14.78, SE_{LDIgen} = .55) and the classroom group (M_{LDIgen} = 15.11, SE_{LDIgen} = .48), t(15.77) = -0.46, ns, r = .11. Conversely, the mobile group ($M_{LDIcons}$ = 16.33, $SE_{LDIcons}$ = .55) described the construction-related aspects in significantly higher detail than the classroom group ($M_{LDIcons}$ = 12.22, $SE_{LDIcons}$ = 1.16), t(11.43) = 3.19, p < 0.01, r = .69. Likewise, the mobile group ($M_{LDIcont}$ = 5.78, $SE_{LDIcont}$ = .28) described the contextual aspects in significantly more detail than the classroom group ($M_{LDIcont}$ = 2.56, $SE_{LDIcont}$ = .69), t(10.53) = 4.34, p < 0.01, r = .80.

Variety of the provided graphical information
The mobile group (M_{VGI} = 4.89, SE_{VGI} = .51) provided significantly more variety in the graphical information than the classroom group (M_{VGI} = 2.11, SE_{VGI} = .75), t(14.09) = 3.05, p < 0.01, r = .63. In addition, the mobile group (M_{NP} = 12.56, SE_{NP} = 1.91) supplied a significantly higher number of photographs in the assignments than the classroom group (M_{NP} = 2.44, SE_{NP} = 1.13), t(12.98) = 4.54, p < .001, r = .78. More specifically, the level of detail provided for each of the photographs for the mobile group (M_{LDP} = 1.67, SE_{LDP} = .17) was significantly higher than that for the classroom group (M_{LDP} = .78, SE_{LDP} = .28), t(13.10) = 2.74, p < .05, r = .60.

Significant differences between separate aspects
The final grade and most of the other dependent variables in the analysis before were composed of several separate aspects on which performance was graded. For a more specific view of the grading data, table 7.1 gives the aspects that were graded significantly different for both groups.

Table 7.1:

Assignment aspects graded significantly different between the treatment groups

Aspect	t	p	r	Mean (SE)	
				Mobile (n=9)	Classroom (n=9)
CA6: Structure	$t(15.49) = 2.13$	< .05	.48	1.67 (.17)	1.11 (.20)
CA8: External walls	$t(8.00) = 2.53$	< .05	.67	2.00 (.00)	1.56 (.18)
CA10: Finishes	$t(8.00) = 3.16$	< .05	.75	0.56 (.18)	0.00 (.00)
TA1: Location	$t(14.19) = 3.78$	< .01	.71	1.67 (.17)	0.56 (.24)
TA2: Urban planning elements	$t(10.32) = 2.87$	< .05	.67	1.89 (.11)	1.00 (.29)
TA3: Environment-related aspects	$t(15.19) = 2.75$	< .05	.58	1.56 (.18)	0.78 (.22)
M1: Number of photographs	$t(16.00) = 4.02$	< .001	.71	1.56 (.18)	0.56 (.18)
M2: Level of detail of the photographs	$t(13.10) = 2.74$	< .05	.60	1.67 (.17)	0.78 (.28)

Table 7.1 shows that for each significantly different graded aspect, the mobile group has a higher mean rating than the classroom group. Appendix D shows that the mobile group has higher mean ratings for twenty out of the twenty-nine aspects, and is only outperformed by the classroom group by four.

DISCUSSION

The results in the last section will be discussed here. First, the software desirability and usability results will be analysed in the next subsection, after which, the learning effectiveness results measured with the assignments will be dealt with in the second subsection.

Software Desirability and Usability

As was mentioned before, mobile learning tools can be used by learners to create learning content in authentic situations and allow them to access it in the classroom context, providing a cross-context scenario that improves the integration of field-trips in the curriculum, and contributing to the improvement of learning. However, in order to motivate the students to use this kind of learning tools sometimes is not

enough to demonstrate the advantages they offer to support learning activities. It becomes necessary to assure that students feel attracted by the mobile technology. It would be beneficial for learning if learners used the learning tools in their own time and integrate it in their daily lives. On the other side, the learning tools that also promote the exchange of opinions, experiences, and knowledge contribute to the creation of social networks that, at the same time, encourage users' learning and the use of the tool itself. The software desirability test results indicate an overall positive attitude of the fieldtrip students towards the developed ContextBlogger software. They used adjectives such us useful, easy to use, attractive, and intuitive, as creative and innovative, as well as entertaining, to define their feelings towards the mobile technology. The usability test results also support these conclusions. Users felt the ContextBlogger mobile tool was attractive and they were motivated by it. Therefore, these results suggest that the introduction of this mobile tool in the building engineering course could have a good acceptance under students, which could contribute to the integration of fieldtrips in the curriculum as well as the exchange of knowledge within a student's social network.

Learning Effectiveness

The results reveal some significant differences in the performance on the assignment between the fieldtrip group and the classroom group. Results show that there were significant differences in the assignment's final grade, as well as on nine of the twenty-nine aspects evaluated. In this section, the results and their possible causes are analysed and discussed according to the dependent variables that were presented earlier.

Final grade for the assignment (FG)
Results show that participants in the mobile group had a significant higher final grade than participants in the classroom group. This difference in final grade suggests that fieldtrips supported by mobile devices in building engineering produce a considerable improvement in student performance. This finding is consistent with previous research studies (De-Marcos et al., 2010, Chu et al., 2010). Although there is statistical evidence of improvement in fieldtrip students' achievement, we are aware that due to the small sample size we cannot generalize from the results. From these results, we can conclude that hypothesis 1, *"the fieldtrip group will obtain a higher final grade for the assignment than the classroom group."*, has been validated.

Number of correctly identified aspects
Several significant differences can be observed between the dependent variables. The mobile group identified a significant higher number of aspects correctly than

the classroom group, which can be explained by analysing the three sub-variables independently.

First, the *number of correctly identified general aspects* does not significantly differ between the mobile group and the classroom group. Aspects such as the name of the building, its architect, its construction year, and architecture typology, can be easily found on the Internet and in other digital and non-digital information resources. Considering that both groups could use this kind of information, they had the same chance to correctly identify these aspects. However, the classroom group performed slightly better on the general aspects.

Second, the mobile group outperformed the classroom group on *the number of correctly identified construction-related aspects*. The significant difference between construction-related aspects is observed in elements such as the building structure, the external walls, and the internal finishes. Other elements such as building foundations, internal partitions, and services did not significantly differ; these elements are not visible during the fieldtrip, hence both the mobile group as the classroom group had the same information to complete these aspects in the assignments. The lower number of construction-related aspects identified by the classroom group could be explained by the lack of knowledge of the existence of some of the building elements or the dismissal of some information as having minor importance. On the contrary, the students in the mobile group, who had visited the building during the fieldtrip, did identify these aspects. Moreover, upon identification the students could take pictures of the aspects and add comments for later addition to the assignments.

Third, there was a significant difference between *the number of contextual aspects correctly identified* by the mobile group and the classroom group. The mobile group was able to discover the building surroundings during the fieldtrip, and therefore could identify characteristic urban planning elements. Considering that some information of the contextual aspects was also available on the web, we feel the classroom students did not consider this information important.

Thus, in general, the mobile group identified more aspects. This effect is mainly caused by significant differences between the construction and contextual aspects. However, while the performance on the general aspects was similar for both groups, the classroom group performed slightly better. Hence, the focus of the classroom group was therefore more on the general aspects, while the mobile group had a broader focus. From these results, we can conclude that hypothesis 2, *"the fieldtrip group will identify more expected aspects correctly than the classroom*

group, particularly construction-related aspects and contextual aspects", has been confirmed.

Level of detail of the information provided
Closely related to the number of correctly identified aspects is the level of detail for each of these aspects, which was also considered. Results indicate that, in general, the mobile group provided a significantly higher level of detail for all of the aspects than the classroom group. The results corresponding to the defined three sub-variables (general aspects, the construction-related aspects, and the contextual aspects) show that there is no significant difference between the mobile group and the classroom group in the level of detail provided for the general aspects. Both groups described most of the general aspects and were rated with a score for the highest level of detail. Thus, for example, they not only identified the building form typology, but also described the main characteristics typical for this kind of typology. Conversely, the mobile group described the construction-related aspects and the contextual aspects in significantly higher detail than the classroom group. This is especially observed in various aspects such as structure, external walls and construction materials. As a particular example, in a classroom student's assignment a picture of the entire building can be found with a text below describing the glass façade in general terms. However, a fieldtrip student not only includes the general description of the façade typology but also adds a brief text and a picture of the system used to join the glass elements. Most of the pictures used to describe detailed aspects of the building have been taken and tagged using the ContextBlogger mobile client during the fieldtrip. This indicates that fieldtrips, supported by the ContextBlogger mobile client, not only could contribute to achieve a broader focus of the subject but also lead to a higher level of detail of the observed aspects in the assignments. Moreover, the number of tags visible in the pictures included in the assignments suggests that students quite often used the tagging system of the ContextBlogger mobile client to annotate detail information of the aspects identified. From these results, we can conclude that hypothesis 3, *"the fieldtrip group will include a greater level of detail for each of the aspects in the assignments than the classroom group"*, has been validated.

Variety of the provided graphical information
Although the variety of the provided graphical information was not included in the final score of the assignment, still the comparison of both treatment groups could be interesting. First, results indicate that the mobile group provided significantly more variety in the graphical information than the classroom group. The graphical information was mainly composed of photographs of the entire building and its elements and, secondly, of sketches of the building design and schemas of the building structure. The significant difference in the variety of the graphical informa-

tion provided was caused by the mobile group supplying a significantly higher number of photographs in the assignments than the classroom group. The higher number can be explained by the ease with which the mobile group could create photographs; the mobile devices provided to the students during the fieldtrip were all equipped with an integrated camera, which allowed them to take pictures of all the interesting elements they found during the fieldtrip. Moreover, the ContextBlogger mobile client made it possible to upload the photographs to the web portal to simplify later retrieval. In addition, the photographs could be annotated with tags and comments, identifying different parts of the photographs. Students used this system to take pictures of the interesting elements that they would later include in their assignments, tagging them with the necessary information to be further extended in text format.

Second, the level of detail provided for each of the photographs was significantly higher for the mobile group than the classroom group. The images provided by the classroom group mainly represent the entire building from different perspectives, even in the description of a specific element of this building. Conversely, the fieldtrip students included more detailed images when appropriate in the assignment and the students had taken most of the images included themselves. Students' comments collected in the desirability test also indicate that the ContextBlogger mobile client contributed to the higher number of photographs included: *"this system allows you to organize and locate your pictures in order to save time and also get a better final result"* and *"the application for the mobile phone is easy to use and this motivates to take photos and put tags on them"*. From these results, we can conclude that hypothesis 4, *"the fieldtrip group will provide a greater variety of information than the classroom group. Especially, the number of photographs and their level of detail will be higher"*, has been validated.

In addition to the results obtained from the rubric, further conclusions may be drawn from the observation of the students' behaviour during the fieldtrip and the results obtained from the desirability test. During both fieldtrip and desirability test, students stated that they liked and saw the usefulness of the social possibilities of the mobile client and portal. Especially, the possibility to see the photographs taken by others was described as interesting, inspiring, entertaining, and useful. In addition, the tagging application received good critique as well; the students stated that the tags attached to pictures helped them to become aware of new building elements. This social interaction was also noticed in the assignments of the mobile group. Some of the pictures taken during the fieldtrip were shared among students. In this sense, connectivity has been identified as one of the benefits of using mobile technologies in education (Liaw, Hatala, & Huang, 2010; Churchill, & Churchill, 2008) and, moreover, collaborative learning experiences in mobile learning experiments

were also reported in previous studies (Looi et al., 2009; Chu et al., 2010). Therefore, we can conclude that the students used the social functionality of the ContextBlogger mobile client to share and exchange ideas and experiences while observing learning objects in the real world, which contributed to cooperation and communication.

CONCLUSIONS AND FURTHER WORK

The analysis, presented above, reveals different effects of a fieldtrip supported by mobile devices on the learning performance of a group of university students. First, the results suggest that fieldtrips contribute to a broader focus of the subject under study, which results in a higher number of identified aspects, and consequently in a better final score. Especially, *a broader focus* could be observed in the higher number of building elements that fieldtrip students added to their assignments; in particular, in the elements related to the construction-related aspects and the contextual aspects. If we consider that both groups had not studied the assigned building before, none of them were aware of the aspects that would be evaluated with the rubric, and information related to all the expected aspects was available for all the students in most of the proposed information resources, it seems that the mobile group was stimulated by the real-world experience, they achieved new perspectives on the building and its elements, and therefore they analysed the building from a broader point of view.

Second, and closely related to the previous reason, results also indicate that the fieldtrip students achieved *a more specific focus* on the building elements than the classroom group. Elements identified with a higher level of detail were graded with a higher score. The results suggest that the fieldtrip group analysed the building elements in a higher level of detail than the classroom group. Aspects such as structure, external walls, and construction materials were described in more detail, by providing photographs and information of their characteristics and elements. In particular, in their assignments, the fieldtrip students included photographs of some building details taken during the fieldtrip. The tags added to these images suggest that students used the ContextBlogger tagging system to collect information of specific parts of the building, which could later be used in the assignments. This could also indicate that fieldtrips, supported by the ContextBlogger mobile client, not only contribute to achieve a broader focus on the subject, but also lead to a more specific focus which resulted in a higher level of detail for the observed aspects.

Third, motivational differences between the mobile group and classroom group could be another reason to understand the different final scores. Previous studies suggest that fieldtrips actively engage participants in their environment, and stimulate and motivate them to learn and gain knowledge about the space in which they are moving (Willis et al., 2009). Additionally, the use of mobile devices during a fieldtrip also promotes learning motivation and engages the students, which can result in an improvement of the learning performance of individual students (De-Marcos et al., 2010; Chu, 2010; Lai, Yang, Chen, Ho, Chan, 2007). De-Marcos et al. (2010) state that this increased motivation is specifically observed among young people. This increased motivation is also reflected in the students' comments in the desirability test after the fieldtrip: *"the system is usable because it motivates us to participate and interact with other students. For this reason we can improve our knowledge"*, and *"the system makes me feel more interested in buildings"*. Therefore, the increased student motivation during the fieldtrip could have had a lasting effect that contributed to the better performance of the fieldtrip students' assignment.

Furthermore, this study indicated that mobile devices, the ContextBlogger system in particular, have a variety of features that can help to pair the benefits of computer-mediated learning with direct real-world experience. First, the system supports the learner in the field and enables the student to sense and record aspects of the local environment; it provides the opportunity to take and annotate pictures. Second, the created content is stored on a web portal, which allows later usage in classroom assignment. Last, the learners can share their own discoveries with others, supporting students' communication and collaboration. The use of this mobile tool in building engineering courses provides a cross-context scenario that improves the integration of fieldtrips in the curriculum, contributing to the improvement of learning.

However, further research could be conducted in this area, enlarging the sample of learners and courses to confirm the validity of the results, or evaluating the long-term effects of the use of the mobile client among the students. In particular then, the separate educational effects of the fieldtrip, the mobile learning software, tagging and other annotations, and the social aspects of the software should be considered. The design of an experiment in three groups (classroom students, fieldtrip students, and mobile fieldtrip students), complemented with a motivational test, could provide interesting information to identify the different contributions to the students' learning performance.

Judging from the usability and desirability tests, the ContextBlogger mobile client and web portal could be improved. The current version of the mobile client only works with Windows Mobile 6.0 devices, and was only tested on HTC Touch Dia-

mond devices; for a wider use of the ContextBlogger software, the software should be ported to other platforms. Moreover, as was found in the desirability results, the usability of the web portal should be improved. Especially, the presentation of the uploaded images that belong to a real-world object should be improved; the students specifically asked for a kind of photo album with thumbnails pictures here. In addition, the social functionality of the portal was valued by the students, and may be improved as well. In this respect, recommendations of created learning content to peers and more extended group functionalities to improve content sharing would be interesting. Furthermore, students could be encouraged to use the system more regularly as part of their daily learning experiences; integration with existing social portals, like for example Facebook, might be a way to accomplish such regular use. Last, augmented reality software presenting information tags on top of a live video feed of the real-world environment are already commonly available on most mobile platforms. It would be interesting to consider the educational effects of an augmented reality extension to the ContextBlogger portal.

CHAPTER 8

The Effects of Task Structure and Interaction History on Mobile Language Learning Performance

ABSTRACT

Mobile devices provide unique opportunities for second language learning in real-world contexts. On the one hand, they can present the learner with appropriate and rich learning content in a real-world situation. On the other hand, mobile devices could also influence the learning context by trying to steer learner behaviour. The study presented here investigates the effects of two task types and two types of interaction history, presented on a mobile device, on second language learner performance. Forty-four secondary school students participated in the evaluation of a mobile language-learning tool that was specifically developed for the study. No effects of task type or type of interaction history were found on total learner performance. Conversely, the task type did influence performance on certain sub-categories of the vocabulary tested. The study established that a mobile learning application can influence the immediate learner focus. In spite of this, no longer-term effects on learner focus were found. Several suggestions to improve long-term learner performance are given.

INTRODUCTION

The personal characteristic of mobile devices and their near ubiquitous availability makes them an ideal tool for second language learning support. Mobile device sensors, like for example GPS and barcode sensors, provide easy ways to adapt learning media to a location and objects in the learner's vicinity. Furthermore, modern smart phones can deliver rich multimedia content that can provide learners with native audio to practice pronunciation or illustrate specific cultural customs visually, via picture or video content. As opposed to web-based e-learning scenarios, mobile access to contextualised rich media content in authentic real-world scenarios enables learners to receive language support that is tailored to their current situation and needs. By supporting interaction in the real world, learners are encouraged to communicate in a target language with native peers.

The importance of communication in a target language has been stressed by several theories of second language learning. While each of the theories has a different viewpoint on language learning, all of them see language learning as an essential social process. First, the input and interaction theories of second language learning emphasise the role of social interaction for target language input, output, and interaction. These theories have been based on two hypotheses. On the one hand, the interaction hypothesis (Long, 1981, 1983, 1996) states the importance of language interaction to increase the comprehensibility and usefulness of language input for the individual language learner. Especially, the role of negotiation of meaning be-

tween a native and non-native speaker is an essential part of the research inspired by this hypothesis. On the other hand, the output hypothesis (Swain, 1985, 1995) states that certain aspects (syntax and morphology) of a second language are most effectively developed in second language production. According to Swain, language output raises consciousness of problems and gaps in current knowledge, can provide opportunities to tests hypotheses about the second language, and allows the language learner to reflect on the language explicitly.

Second, the sociocultural perspectives to second language learning are grounded in sociocultural and activity theory (Vygotsky, 1962, 1978) in which language is seen as a tool for making meaning in the collaboration with target language speakers. Thus, the sociocultural perspectives also consider language interaction but their emphasis is more on the social motive for second language learning. In this sense, the emphasis of these theories is on self-regulation through private speech to gain control over the language task (Frawley, & Lantolf, 1985), the influence of personal characteristics and interests on social interaction (Coughlan, & Duff, 1994; Roebuck, 2000), and language feedback of native speakers to scaffold a second language learner (Aljaafreh, & Lantolf, 1994; Nassaji, & Swain, 2000).

Last, the sociolinguistic perspectives consider the second language learner as part of communities of practice and investigate the role of the learner's identity, emotions, and social position in a learner's development of a second language (Bremer, Roberts, Vasseur, Simonot, & Broeder, 1996; Heller, 1999; Norton, 2000; Ochs, & Schieffelin, 1995; Pierce, 1995; Wenger, & Lave, 1991). Moreover, the sociolinguist perspectives see language learning as a situated activity, in which the influence of the learning context on the learner is essential. Summarising, the second language theories mentioned here all emphasise the social aspect of language learning in which both language production as language input in real-world scenarios with target language speakers are important. In this sense, mobile devices provide new possibilities to offer support to second language learners in authentic settings independent of time, place, and in a target language community.

A variety of studies already investigated the opportunities of mobile devices for language learning. Kukulska-Hulme and Shield (2007) distinguish between using mobile devices in a more passive manner for learning content distribution on the one hand, and using them to encourage learner interaction in a target language environment on the other. Most of the current mobile language learning studies aim at the former content distribution and offer vocabulary training in previously unused time slots, instant lookup of vocabulary anytime and anyplace, and repetition in the form of quizzes and surveys. For example, Levy and Kennedy (2005) describe learning Italian vocabulary via SMS messages that were sent at specific time

intervals. Likewise, Fisher et al. (2009) provide an example of an extended e-book reader that allows the second language learner to instantly look up vocabulary and listen to a native pronunciation. Last, Thornton and Houser (2005) investigated the effects of e-mails with English vocabulary sent to mobile devices owned by Japanese students, and described the combination of textual information (explanations, quizzes) and video material for mobile language learning. In contrast with these more passive language-learning approaches, mobile learning solutions supporting target language interaction are largely left unconsidered (Petersen, & Divitini, 2005). To address this lack of solutions Petersen and Divitini (2005) provide two scenarios for community-based mobile language learning, one of which focuses on interaction between students in a native and students in a non-native environment. Similarly, Kukulska-Hulme and Shield (2007) in their review of mobile language learning also emphasise the importance of real-world interaction, and stress the lack of mobile language learning solutions for speaking and listening. An interesting example of a context-aware mobile language learning system aimed at real-world interaction is JAPELAS (Ogata & Yano, 2004) that provides the learner with the correct Japanese politeness expressions based on a learner profile, location, and the person addressed. What is more, Ogata and Yano (2004) present TANGO, a mobile learning system that uses RFID-tagged real-world objects to teach vocabulary. Another example of mobile support for language interaction is the LOCH system that supports second language learners to carry out tasks in a Japanese target language environment (Paredes et al., 2005; Ogata et al., 2006). In addition, the tasks carried out with LOCH were all focused on communication in the target language and were supported by a teacher who could view the GPS location of the students to give location-specific feedback.

While already a couple of studies have explored real-world applications of mobile technology to support language learning, a lot of applications are isolated small-scale pilot studies. Recent efforts to come to a theory of mobile learning try to provide a common framework (Koole, 2009) to structure mobile learning research. One such theory takes activity theory as a starting point (Sharples, Taylor, & Vavoula, 2007) and sees mobile devices as artefacts mediating learner behaviour. Sharples et al. (2007) distinguish three factors in technology-mediated mobile learning: (1) *control*, the way in which learning is delivered and the extent to which the learners can control this delivery to their own preferences, (2) *context*, which can denote context information acquired and modelled in a technological system, a learning context arising from an interaction between a learner and the technology, and a social context of the learner within a community, and (3) *communication,* the communication between learners, which can be mediated and influenced by mobile technology. These three factors form a basis along which technology-mediated mobile learning can be studied. In the study presented here, the authors will con-

trast two forms of learning control and investigate the use of contextual information in mobile learning support. The communication factor will not be considered in this study.

In this study, learner control is varied on the task level. From a wealth of studies into the structure of complex tasks it becomes clear that the way task information is presented influences learner effectiveness and performance (Van Merriënboer, 1997; Sweller, Van Merriënboer, & Paas, 1998; Kester, 2003; Kester, Kirschner, & Van Merriënboer, 2006). In specific, the amount of learner guidance seems to influence the learner effectiveness (Kirschner, Sweller, & Clark, 2006): no or minimal learner guidance is reported to be less effective than guided instruction. As most of these studies address non-mobile forms of learning, it would be interesting to see what results are transferable to mobile settings. In the context of learner control, the difference between several levels of learner guidance is worth considering. In the study presented here, a mobile language-learning tool to carry out vocabulary learning tasks is evaluated. To investigate learner performance with different forms of guidance, two types of task are evaluated. The first type of task, the structured task, explicitly states part of the vocabulary the learner has to gather to perform an authentic real-world task, whereas the second type of task, the unstructured task, leaves it up to the learner which vocabulary is collected. It is expected that different forms of guidance will lead to different learning behaviour, and possibly to differences in learner performance.

Several forms of contextual information are compared in this study. Apart from task context and object identity context, the study focuses on the effects of two forms of history context that explicitly show the learner's interactions with the learning content. The interaction history provides an additional perspective on the learning content to that of the tasks. According to Cognitive Flexibility Theory (Spiro, Coulson, Feltovich, & Anderson, 1988) multiple representations of learning content are important for learning. Two types of interaction history are compared in this study and evaluated on their effectiveness. The first alternative, time-based history, provides the vocabulary accessed by the learner dependent on the time. The second alternative, room-based history, provides the vocabulary accessed by the learner dependent on the location. Both types of interaction history present another form of information organisation and stimulate the learner's memory in different ways. It is expected that both types of interaction history make the learners more aware of the actions carried out before, and affect their episodic memory (Tulving, 1983, 2002). While it is not entirely clear in what way both types of interaction history affect the episodic memory, we anticipate the time-based interaction history to be more similar to the way the autobiographical memory is organised and to result in a better long-term recollection of the vocabulary learnt. Conversely, the effectiveness

of a certain history filter may also depend on the way the learners organise their learning. If learners organise their learning on a task-by-task basis then the time-based history context would prove more effective, because the vocabulary is organised in the order the tasks were carried out. Alternatively, should the learners decide to access the content on a room-by-room basis, and gather all the learning content independent of the tasks, the room-based history context would provide a perspective more helpful for the learners.

In this paper, an evaluation of four variations of mobile language-learning software is carried out, investigating different combinations of task type and type of interaction history. For this study, we adapt a framework for evaluating mobile learning from a technological (desirability, usability) and an educational perspective (effectiveness) that was proposed in Sharples (2009). The results of the evaluation with this framework will be presented in this paper.

METHOD

Design

The study used a between-groups design. There are two independent variables: the task variable (with two levels: structured and unstructured) and the interaction history variable (with two levels: time-based and room-based). Furthermore, three dependent variables were used in this study: the immediate knowledge gain (KG), the longer-term knowledge gain (KGR), and the knowledge retention (KR). Additionally the usability and desirability of the software was measured.

The Independent Variables
The task variable manipulated the kind of language learning tasks the participants were given. Each task consisted of a description of an activity the participants had to perform and for which they needed to learn a collection of words. In each task description ten words out of the entire vocabulary were used. Two types of tasks were used: structured tasks and unstructured tasks. The structured tasks gave some guidance to complete the task: next to the task description, a list of five words the participants needed to collect was given. Conversely, the unstructured tasks gave no additional guidance to complete the task; a task description was given, but a list of words to be collected was omitted. An example of a structured task can be found in appendix E.

The interaction history variable manipulated the kind of interaction history the participants received in the mobile client software. Two types of interaction history

were used: time-based interaction history and room-based interaction history. The time-based interaction history displayed the language content interacted with or-dered by time; the content accessed last is displayed first in the list. Alternatively, the room-based interaction history organised the learning content according to the room the objects with the language content were situated in; the learning content was categorised by room and subsequently ordered alphabetically.

Each treatment variation in the study employed a different combination of the task variable and the interaction history variable, all of which are given in Table 8.1.

Table 8.1:
Overview of the four combinations of task and interaction history used in each experimental variation

Interaction History		
Task	Time-based	Room-based
Unstructured	UTT	UTR
Structured	STT	STR

The Dependent Variables
Three dependent variables measuring learner performance were used in this study. In addition, desirability and usability measurements were carried out for each of the treatments.

The first dependent variable, *the immediate knowledge gain (KG)*, was calculated with the following formula:

$$KG = (\sum KQpost_i - \sum KQpre_i) / i, \text{ where } i = 40. \tag{8.1}$$

Equation 8.1 calculates the immediate knowledge gain for one participant, as a ratio, by subtracting the total number of correct answers for the pre-test ($\sum KQpre$) from the number of correct answers for the post-test ($\sum KQpost$), and dividing the result by the total number of questions in the test i. The minimum immediate know-ledge gain is therefore 0; the maximum immediate knowledge gain equals 1. The immediate knowledge gain measures the difference in learner performance be-tween the pre-test and the post-test just after the experiment.

The second dependent variable measures *the longer-term knowledge gain (KGR)* with respect to the pre-test, and was calculated with the following formula.

$$KGR = (\sum KQret_i - \sum KQpre_i) / i, \text{ where } i = 40. \tag{8.2}$$

Equation 8.2 calculates the longer-term knowledge gain for one participant, as a ratio, by subtracting the total number of correct answers of the pre-test ($\sum KQpre$) from the number of correct answers of the retention-test ($\sum KQret$), and dividing the result by the total number of questions in the test i. The minimum longer-term knowledge gain is therefore 0; the maximum longer-term knowledge gain equals 1. The longer-term knowledge gain measures a difference in learner performance between the pre-test and the retention-test a week after the experiment.

The third dependent variable, *the knowledge retention (KR)*, was calculated with the formula:

$$KR = KGR - KG = (\sum KQret_i - \sum KQpost_i) / i, \text{ where } i = 40. \tag{8.3}$$

Equation 8.3 calculates the knowledge retention for one participant, as a ratio, by subtracting the total number of correct answers of the post-test ($\sum KQpost$) from the number of correct answers of the retention-test ($\sum KQret$), and dividing the result by the total number of questions in the test i. The minimum knowledge retention is therefore 0; the maximum knowledge retention equals 1. The knowledge retention measures the difference between the performance just after the experiment and the performance after one week.

For each of the dependent variables, two sub-variables were specified. The first sub-variable measured the immediate knowledge gain, longer-term knowledge gain, or knowledge retention, on the words that were explicitly given in the structured tasks: KG_{task}, KGR_{task}, and KR_{task} respectively. The second sub-variable measured the knowledge gain or knowledge retention on the words that were hidden in the task descriptions: KG_{hidden}, KGR_{hidden}, and KR_{hidden} respectively.

The usability evaluation was carried out with a standardised toolkit measuring the hedonic and pragmatic quality of the software (Hassenzahl, Burmester, & Beu, 2001; Hassenzahl, Platz, Burmester, & Lehner, 2000). In specific, the usability evaluation measured (1) the pragmatic quality (PQ), that describes how successful the users are reaching their goals using the software, (2) the hedonic quality – identity (HQ-I), which describes to what extent users identify themselves with the product, (3) the hedonic quality – stimulation (HQ-S), which measures to what extent the users experience the software as innovative and stimulating, and (4) the attractiveness (ATT), which describes a global quality value for the product. The desirability evaluation of the software was done using the Microsoft Desirability Toolkit (Benedek & Miner, 2002).

Hypotheses

In the study the following hypotheses were investigated:

Hypothesis 1: *the participants with structured tasks will have a significantly higher immediate knowledge gain (KG) and knowledge retention (KR) than the unstructured tasks*. Differences in learner guidance could cause differences in learner performance. In this case, we expect that the structured tasks, providing more guidance, will lead to a better learner performance than the unstructured tasks.

Hypothesis 2: *the participants with time-based interaction history will significantly outperform the learners with a room-based interaction history on immediate knowledge gain (KG) and knowledge retention (KR).* On the one hand, a time-based interaction history gives a historic view of how the different words for the tasks were collected, strengthening the effect of the task organisation if the words were collected per task, and strengthening the effect of the organisation per room if the words are collected per room; in contrast, a room-based interaction history only strengthens the effect of the organisation if the words were collected by room. On the other hand, participants with a time-based interaction history can use a task-based organisation, a time-based organisation, and the room-based organisation in the authentic environment to structure their learning, as opposed to participants with a room-based interaction which can only use the task-based organisation, and a room-based organisation (both on the mobile as in the authentic environment). Because the participants with the time-based interaction history have a higher number of ways to structure their learning, it is expected that time-based treatments will outperform the room-based both on immediate knowledge gain (KG) as knowledge retention (KR).

Hypothesis 3: *Mobile devices can influence learner focus via the learning tasks delivered*: the structured tasks given via mobile devices will lead to a different learner focus, thus a different set of words learnt, than that for the unstructured tasks.

- Hypothesis 3a: the structured task treatment groups will have a significantly higher KG_{task} than those with the unstructured tasks; the immediate focus of the learners in the structured task groups is on the words explicitly given in the task description, therefore they are expected to outperform the unstructured task groups on these words.
- Hypothesis 3b: *the unstructured task treatment groups will have a significantly higher KG_{hidden} than those with the structured tasks*; the immediate focus of the learners in the unstructured task groups is on all words available in the task descriptions. Therefore, they have a broader focus and are expected to outperform the structured task groups on the words that are not explicitly part of the structured task descriptions.

- Hypothesis 3c: the structured task treatment groups will have a significantly higher KGR_{task} than those with the unstructured tasks; a similar effect as was measured by hypothesis 3a is expected on the long-term.
- Hypothesis 3d: the unstructured task treatment groups will have a significantly higher KGR_{hidden} than those with the structured tasks; a similar effect as was measured by hypothesis 3b is expected on the long-term.

Participants

Forty-four students (30 male, 14 female; M = 16.43 years, SD = 1.02) of several secondary schools in Heerlen, the Netherlands, participated in this study. All participants spoke Dutch fluently, and therefore instructions and questionnaires were given in the Dutch language. Participants were randomly and evenly distributed over the four treatments (see table 8.1). As a compensation for their participation students received an iTunes voucher of 15€.

Apparatus

Participants were equipped with an iPhone 3G (http://www.apple.com/iphone/) or iPod Touch device that contained the language learning software specific to the treatment they were assigned to. The language learning software made it possible to access language content related to objects in the real world, by entering a numeric code attached to these objects. The learning content consisted of a picture of an object, a textual representation of the Hindi word for the object, a translation, and an audio fragment for the word created by a native speaker. For each of the treatments in table 8.1 another variation of the mobile language learning software was developed. While the general user interaction was similar across all variations, the different clients had a specific UI for the structured and unstructured tasks respectively, and filtered the interaction history either by time, or by room. All actions carried out with the software were logged. The software was developed using the Objective C language and Apple's iPhone SDK.

Figure 8.1 shows the "Tasks" screen (left) that shows the tasks the participant has to gather the words for. Selecting a task in the list shows a more detailed view for that task. Depending on the treatment, the participant is either shown an unstructured task (middle) or a structure task (right). Both views contain the task title, the same task description, and a button to access the items that were collected for that task. For structured tasks, an additional list of words that have to be collected is given, in this case: tea, cup, milk, monkey, and chair.

Figure 8.1: The list of tasks on the mobile device (left), and the two variations of task descriptions, unstructured (middle) and structured (right)

Figure 8.2 shows the process of adding a word to the collection of words for a task. After tapping the "Show Items" button in the task view (see figure 8.1), the "Items For Task" view (right) is displayed. The participant can add a new word by tapping the plus-sign button on the top and entering the numeric code for the object in the "Scan" view that is shown left. If a correct code is entered, language content is shown for that object, in this case "paanee" (middle). The language content consists of a Hindi word "paanee", the English translation "water", a picture of the object, and a Hindi audio fragment that can be accessed by tapping the "Play" button. Furthermore, using the "Volume" slider the participant can regulate the volume of the audio. Objects can be added to the "Items for Task" list by tapping the "Add to List" button. The right-most picture in figure 8.2 shows the "Items for Task" after the word "paanee" has been added. The participant can now access the content for that word by tapping the item in the "Items for Task" list.

Figure 8.2: Adding a word to the list of words for a task, (1) entering the object code (left), (2) viewing the word content (middle), and (3) the updated list of words for a task after "Add to List" has been pressed in the middle view

Last, figure 8.3 shows the two variations of interaction history that can be shown in the "History" tab. The first variation (left) shows the time-based interaction history in which the words are displayed in the order the participant accessed them; the item accessed last is show on the top of the list. The second variation (middle) shows the room-based interaction history, in which the words are ordered according to the room they can be found in. Moreover, for each room the words are listed alphabetically. The right-most screenshot gives the content view for the history view; except for the "Add to List" button it is similar to the content view from figure 8.2.

Figure 8.3: The two types of interaction history: time-based (left) and room-based (middle); the right-most screenshot displays the content view that is shown when an item is selected in the history view

Procedure

The experimental procedure consisted of four phases: a pre-test phase, a learning phase, a post-test phase, and a retention-test phase. In the pre-test phase the participants were randomly assigned to one of the four treatments and given a pre-test questionnaire to complete. Depending on the treatment the participants were given a task description for either a structured task (see Appendix E), or an unstructured task. Both task descriptions listed four authentic tasks for which vocabulary had to be collected. The last part of the pre-test phase was a short explanation of the software and the learning task ahead. The pre-test phase was immediately followed by the learning phase. During the learning phase, participants were equipped with an iPhone 3G or a first generation iPod Touch that had a version of the software preinstalled, according to the treatment they were assigned to. In the learning phase, the participants had to explore six rooms in the CELSTEC Media lab, all of which had a number of posters which each depicted an object (see figure 8.4). All participants were given exactly forty minutes to collect the Hindi vocabulary necessary to carry out the four tasks.

Figure 8.4: Participant in the experimental setting; a room equipped with posters depicting various objects

The post-test phase, directly after the learning phase, consisted of a post-test questionnaire testing the vocabulary learnt, the usability evaluation, and the desirability evaluation. Last, the retention-test phase was comprised of a retention-test questionnaire that tested how much of the vocabulary the participants remembered. The retention-test questionnaire was sent one week after the learning phase. The pre-test, post-test, and retention-test all used the same questions to test the vocabulary learnt.

RESULTS

The results for desirability, usability, knowledge gain, and knowledge retention will be considered separately below.

Desirability

The desirability questionnaire revealed that the participants had an overall positive attitude towards the software. Twenty participants rated the software as easy to use. Other terms participants often used to describe the software were: fun, creative, efficient, useful, innovative, and timesaving. The participants thought the software was simple in design and usable by everyone: "Nowadays everyone's quite

used to using electronic devices. So everyone should be able to use this immediately." More specifically, in their opinion, the software was organised and had a clear structure.

Moreover, the practical application of the software and the value of using commonly available devices to simplify learning was recognised by most participants: "I think it can be very useful to teach people my age foreign languages, because they already spend so much time on their cell phone, they might as well do something useful!" In this respect, the motivational aspects of modern mobile technology in general, and the experimental setup in specific were identified as well. Participants stated that they felt the experimental setup was something of a search game, that the primary focus was on the gathering of words, and that while it did not feel like learning they were quite occupied by the activities and felt they learnt quite effectively: "because of the task you are really focused on searching which helps because you want to find the word. I've never been so occupied with learning". In addition, the use of several modalities of learning content was thought of as efficient, time-saving, and helpful for learning: "I think it saves a lot of time. Because you can form an image of the words by the pictures available, it is somehow possible to remember them better and faster". Participants also compared the mobile learning scenario with the more traditional scenario of learning a language with a book; they thought the software to be easier and faster and saw additional value in the supplied audio content: "it's handy because you learn faster and easier than with a book. In addition you can hear the audio so you immediately know how to pronounce the word. And it is not as boring as learning from a book".

The participants saw the practical application of using the software on-the-spot, in authentic environments, and accessing learning content anywhere and anytime. Especially, the possibility of language support in a conversation with a native speaker was valued: "this programme is very useful if you, for example, are having difficulties in a conversation with a person that speaks a different language. In any case, you can make yourself understood then." Likewise, the authentic tasks that were given, and the possibility to organise and repeat the words corresponding to the tasks were equally appreciated: "you learn the words that belong to the tasks and because one performs different tasks, one learns different words. Because the tasks were different from each other, you learn the words that are applicable in different situations". Next to the authenticity, the participants also liked the personal nature of the software: "you learn words for tasks that you would do yourself too". Last, a bug in software caused it to sometimes crash, which for some participants resulted in lost information and some frustration.

Usability

The usability of the developed mobile client variations was separately measured for each treatment group using a standardised usability evaluation. The mean values for each of the usability aspects are reported for each treatment group in figure 8.5. The usability measures are reported on a scale of -3 to 3, where a higher value corresponds to a better score.
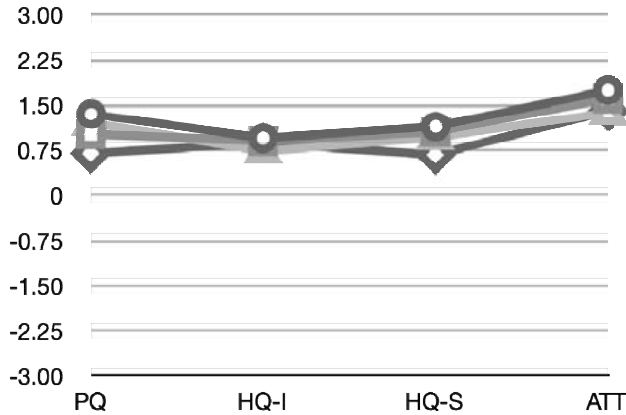
Figure 8.5: Usability measures (PQ, HQ-I, HQ-S, ATT) for the four different treatment groups: UTT(circles), UTR(squares), STT(triangles), and STR(diamonds)

Figure 8.5 shows that overall the UTT treatment group performs best, while the STR treatment group performs worst in terms of usability. This is confirmed by the overall rating that was given by the usability test; the UTT treatment's user interface was rated as "rather desired", the UTR and STT treatment's as "fairly practice-oriented", and the STR treatment's as "neutral". Moreover, a one-tailed t-test revealed that the overall ratings given to the UTT treatment group (M = 1.30, SE = .14) are significantly higher than the ratings given to the STR group (M = .91, SE = .14), t(53.93) = 1.98, p < .05, r = .26. All other differences between treatment groups were found to be non-significant.

The pragmatic quality (PQ) ratings differed across the treatment groups: while the UTT treatment group's user interface was rated as pragmatic, the UTR, STT, and STR treatments were regarded as not clearly pragmatic. Conversely, the total hedonic quality (HQ) was rated similarly for each of the treatment groups and reached only average values. On the one hand, the rating for HQ-I was similar across all treatments, and was located in the average region. On the other hand, the HQ-S was rated as above average for the unstructured treatment groups (M = 1.10, SE = .15)

and as average for the structured treatment groups (*M* = .82, *SE* = .20), yet, this difference was not found to be significant, *t*(24.69) = 1.12, *ns, r* = .22. The attractiveness (ATT) of the user interfaces in all treatment groups was regarded as very attractive.

Knowledge Gain

Table 8.2 shows the mean total knowledge gain (KG_{total}) and standard errors for all treatment groups, where a higher knowledge gain corresponds to a better immediate learner performance on the tasks. In addition, table 8.2 shows the mean knowledge gain and standard errors for all words explicitly given in the structured tasks (KG_{task}), and the mean knowledge gain for the additional words hidden in the task description (KG_{hidden}).

Table 8.2:
Mean (*M*) Knowledge Gain (KG) and Standard Error (*SE*) for each of the treatment groups

	Interaction History			
Task	Time-based		Room-based	
Unstructured	*M*	*SE*	*M*	*SE*
KG_{task}	.23	.02	.24	.06
KG_{hidden}	.25	.05	.20	.05
KG_{total}	.24	.03	.22	.05
Structured				
KG_{task}	.41	.07	.40	.08
KG_{hidden}	.05	.04	.04	.03
KG_{total}	.23	.05	.22	.04

Kruskal-Wallis tests were carried out as the homogeneity of variance and normality assumptions for Anova were violated. Comparisons on immediate knowledge gain were carried out on the treatment level, on task type, and type of interaction history. The results for KG_{total}, KG_{task}, and KG_{hidden} will be considered separately below.

The total immediate knowledge gain KG_{total} was not affected by the type of treatment, *H*(3) = 0.26, *ns*. The boxplot in figure 8.6 confirms the similarity between treatment groups for KG_{total}; the UTT treatment, the UTR treatment, and the STR treatment all have similar medians. Moreover, the comparisons on task type reveal that there were no significant differences in KG_{total} between the structured (*Mdn* = .21) and the unstructured task group (*Mdn* = .25), *U* = 222.50, *z* = -.459, *ns*. In addition, the type of interaction history used had no significant effect on KG_{total}, *U* =

233.00, z = -.212, *ns*, either. The total immediate knowledge gain is therefore not affected by treatment, task type, or type of interaction history.
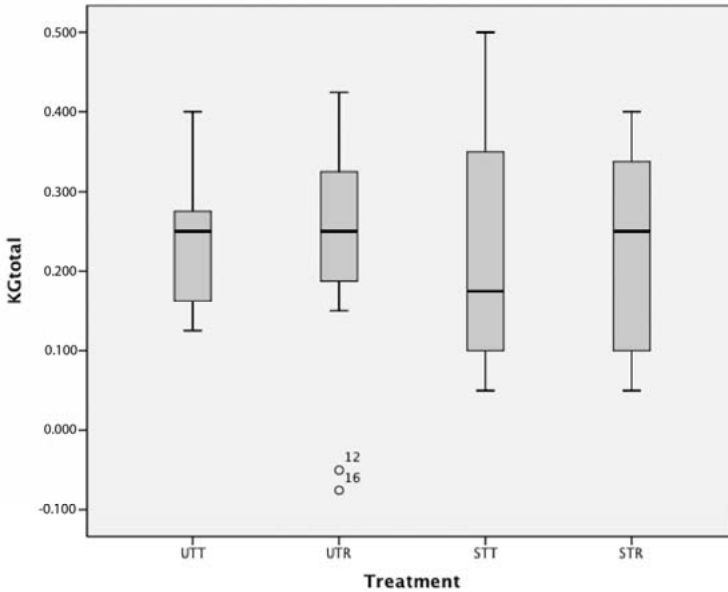
Figure 8.6: Boxplot of total knowledge gain (KG$_{total}$) for each of the treatment groups (Treatment)

The immediate knowledge gain for the words specified in the structured tasks, KG$_{task}$, was not significantly affected by treatment type, $H(3)$ = 5.18, *ns*. In contrast, the task type did have an effect on KG$_{task}$; KG$_{task}$ was significantly higher for the structured task group (*Mdn* = .40) than for the unstructured task group (*Mdn* = .20), U = 337.50, z = 2.26, p < .05, r = .34. Indeed, figure 8.7 shows that both structured treatment groups have higher medians than both unstructured treatment groups. The effect of the type of interaction history used did not affect KG$_{task}$ significantly, U = 234.00, z = -.19, *ns*. Thus, while KG$_{task}$ was not affected by treatment or type of interaction history, the task type did have a significant effect on KG$_{task}$.
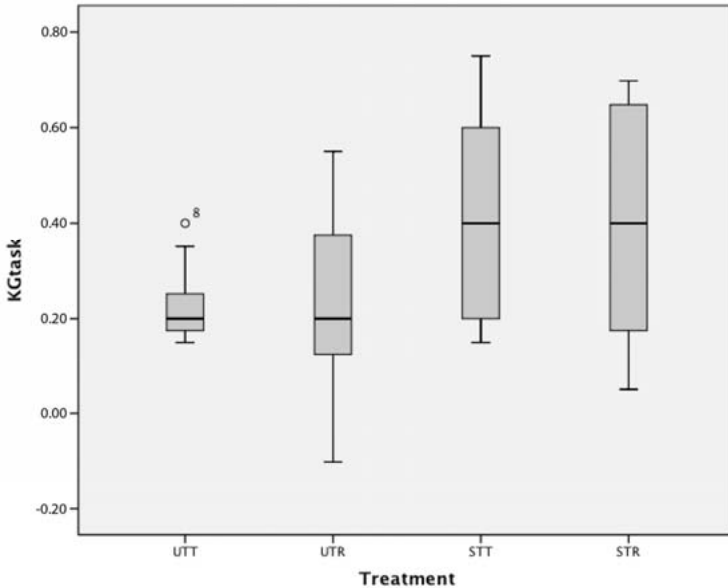
Figure 8.7: Boxplot of knowledge gain of the words given in the structured task (KG$_{task}$) for each of the treatment groups (Treatment)

The type of treatment significantly affected KG$_{hidden}$, $H(3) = 14.19$, $p < .01$. Four Mann-Whitney tests were used to follow up this last finding, comparing both un-structured treatment groups with the structured treatment groups. A Bonferroni correction was applied and thus all effects are reported at a .0125 level of signifi-cance. A significant difference for KG$_{hidden}$ was found between the UTT treatment and the STT treatment ($U = 22.00$, $r = -.54$), the UTT treatment and the STR treat-ment ($U = 16.00$, $r = -.63$), and the UTR treatment and the STR treatment ($U = 21.00$, $r = -.56$). The difference between the UTR treatment and the STT treatment was not significant ($U = 25.00$, $z = -2.34$, $p = .019$, $r = -.50$). In addition, comparisons on task type reveal significant differences: the structured task group ($Mdn = .05$) had a sig-nificantly lower rating for KG$_{hidden}$ than the unstructured task group ($Mdn = .22$), $U = 84.00$, $z = -3.73$, $p < .001$, $r = -.56$. This is also confirmed by figure 8.8, where the treatments with an unstructured task type both have higher medians than the structured task treatment groups. The type of interaction history used did not sig-nificantly affect KG$_{hidden}$, $U = 219.50$, $z = -.53$, ns. Hence, KG$_{hidden}$ is significantly af-fected by both treatment and task type, in contrast to the type of interaction history that has no significant effect.
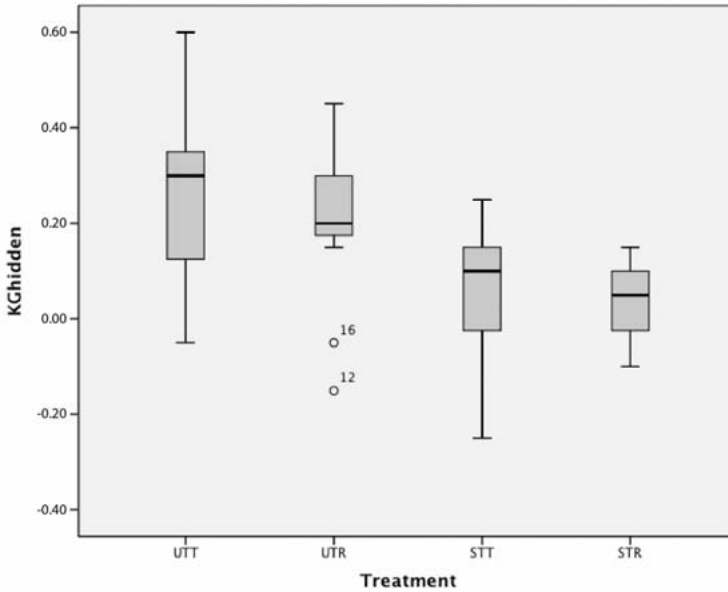
Figure 8.8: Boxplot of knowledge gain of the hidden words (KG$_{hidden}$) for each of the treatment groups (Treatment)

The type of interaction history used does not have any significant effect on any of the comparisons on the immediate knowledge gain. In the post-test questionnaire almost all participants indicated that they rarely used the interaction history tab. Analysis of the log data of the participants' interactions with the software confirms the interaction history was used by only 27 out of 44 participants and only for short periods of time (M = 39s, SE = 14s). The rare use of the interaction history makes any results for this variable questionable; further analyses on interaction history have been therefore omitted in the following sections.

Knowledge Retention

The knowledge retention test measured the number of words the participants remembered correctly and was sent after one week. The average time to answer the retention test was 9 days. Two participants did not fill out the retention test questionnaire.

Table 8.3 shows the means and standard errors for all of the treatment groups, for the total knowledge retention (KR$_{total}$), the knowledge retention for all words given in the structured tasks (KR$_{task}$), and the knowledge retention for all the other words hidden in the tasks (KR$_{hidden}$). A higher value for the knowledge retention corre-

sponds to a better retention. The negative values for almost all mean knowledge retention values indicate a decline in the number of correct answers between the post-test and the retention test.

Table 8.3:
Mean (*M*) Knowledge Retention (KR) and standard error (*SE*) for each of the treatment groups

	Interaction History			
Task	Time-based		Room-based	
Unstructured	*M*	*SE*	*M*	*SE*
KR$_{task}$	.02	.05	-.15	.04
KR$_{hidden}$	-.09	.05	-.18	.07
KR$_{total}$	-.04	.04	-.17	.04
Structured				
KR$_{task}$	-.09	.03	-.15	.03
KR$_{hidden}$	-.10	.03	-.00	.04
KR$_{total}$	-.09	.03	-.08	.03

The longer-term effects on task performance for all words, the words present in the structured tasks, and the additional words hidden in the task descriptions, will be considered separately below.

Longer-term effects on the total retention and knowledge gain: KR$_{total}$ and KGR$_{total}$
The within-subjects difference between post-test and retention-test performance (KR$_{total}$) was highly significant, $F(1, 38) = 27.49$, $p < .001$, $r = .65$. This indicates a significant decline between the number of correct answers given in the post-test (*M* = 19.35, *SE* = .81), and the number of correct answers in the retention test (*M* = 15.64, *SE* = .76). Moreover, the interaction between KR$_{total}$, the task type, and the type of interaction history was also significant $F(1, 38) = 4.27$, $p < .05$. However, post-hoc tests with a Bonferroni correction revealed no significant differences in KR$_{total}$ between the treatment groups. All other within-subject comparisons on KR$_{total}$ were found to be non-significant. A comparison between the pre-test and retention-test to measure the total longer-term knowledge gain, KGR$_{total}$, was highly significant, $F(1, 38) = 38.41$, $p < .001$, $r = .71$. This indicates a significant increase in the total number of correct answers between pre-test (*M* = 10.05, *SE* = .51) and retention-test (*M* = 15.55, *SE* = .82).

Longer-term effects on retention and knowledge gain of the words present in the structured tasks: KR$_{task}$ and KGR$_{task}$
The within-subject difference between post-test and retention-test, KR$_{task}$, was also found to be highly significant, $F(1, 38) = 22.88$, $p < .001$, $r = .61$. Thus, in terms of

KR_{task} there is a significant decline in number of correct answers given in the post-test (M = 12.05, SE = .58) and the number of correct answers given in the retention-test (M = 10.10, SE = .57). All other within-subject comparisons for KR_{task} were non-significant.

The knowledge gain between pre-test (M = 5.47, SE = .38) and retention-test (M = 10.17, SE = .51) for the words in the structured tasks, KGR_{task}, was significant, $F(1, 38)$ = 57.69, p < .001, r = .78. Comparisons between pre-test and retention-test were made for each of the treatment groups, which revealed significant differences for the UTT treatment group, $t(9)$ = 7.57, p < .001, r = .93, the STT treatment group, $t(9)$ = 5.86, p < .001, r = .89, and the STR treatment group, $t(10)$ = 3.58, p < .01, r = .75. The difference between pre-test and post-test for the UTR treatment group was found to be non-significant, $t(10)$ = 1.22, ns, r = .36. The interaction between KGR_{task} and task type was also found to be significant, $F(1, 38)$ = 4.34, p < .05, r = .32. Again, the structured task group (M = .30, SE = .05) has a significantly higher number of correct answers for the words in the structured tasks than the unstructured task group (M = .17, SE = .04).

Longer-term effects on the retention and knowledge gain of the additional words hidden in the tasks: KR_{hidden} and KGR_{hidden}
The within-subject comparisons of post-test and retention-test on the words hidden in the tasks, KR_{hidden}, was found to be highly significant, $F(1, 38)$ = 13.21, p < .01, r = .51. There was a significant decline in the number of correct answers given for the hidden words in the post-test (M = 7.28, SE = .45) and the number of correct answers in the retention-test (M = 5.47, SE = .41). All other within-subject comparisons were found to be non-significant. The comparison of pre-test and retention-test KGR_{hidden} was found to be non-significant, $F(1, 38)$ = 2.41, ns, r = .24. A comparison of pre-test with retention-test for each treatment group, revealed a significant increase in the number of correct answers for the UTT treatment group only, $t(9)$ = 2.55, p < .05, r = .65. Thus, for all of the other treatment groups there was no significant difference between the number of correct answers given in the pre-test and retention-test for the words hidden in the task descriptions.

Overall effects: pre-test, post-test and retention test compared
Figure 8.9 displays the mean differences in the total number of correct answers for the pre-test, the post-test, and retention-test questionnaires. The increase in the number of correct answers between pre-test and post-test (line between 1 and 2) was significant, $F(1, 40)$ = 118.95, p < .001, r = .87. Moreover, while the number of correct answers significantly decreased between the post-test and retention-test questionnaire (between 2 and 3), $F(1, 38)$ = 27.49, p < .001, r = .65, the number of

correct answers in the retention-test is still significantly higher than the number of correct answers in the pre-test (between 1 and 3), $F(1, 38) = 38.41$, $p < .001$, $r = .71$.
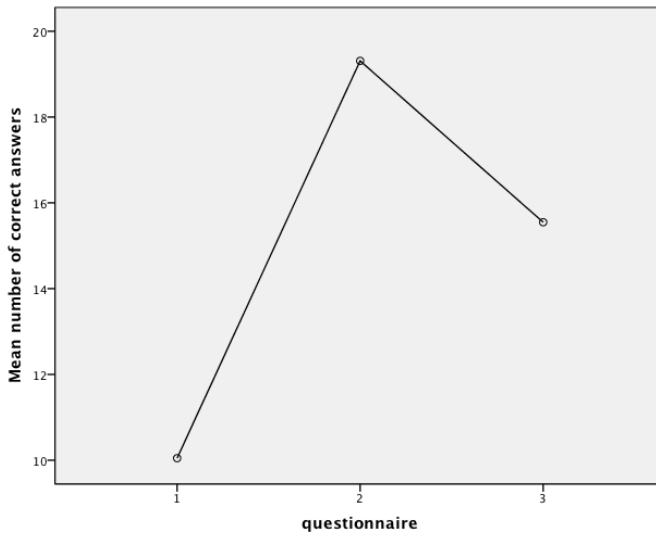
Figure 8.9: Mean differences between the number of correct answers given for each type of question-naire (1 = pre-test, 2 = post-test, 3 = retention-test)

DISCUSSION

The results will be discussed in separate subsections below. The first subsection will discuss the desirability and usability results, whereas subsections two and three will discuss the immediate learner performance and the longer-term performance respectively. Subsection five will provide an overview of overall effects. The last subsection gives some ideas for further work.

Desirability & Usability

The desirability questionnaire filled out by the participants revealed a positive attitude towards the software. The positive attitude was emphasised by the participants regarding the software as very attractive in the usability test. We think especially the game-like setup of the experiment and the use of modern mobile technology, as opposed to the traditional books, resulted in the student's enthusiastic attitude towards the software. The participant recognised the practical application of the software in conversations with native peers. Moreover, the participants thought the authentic tasks used in the experiment helped them to learn words applicable in various real-life situations in an organised way. In addition, the participants stated

that the availability of multiple modalities of information helped them learn better and faster.

The usability test revealed the UTT treatment group as the most pragmatic. We think the support provided by the time-based history filter and the unstructured task in the UTT treatment reflects the informal learning in an authentic setting better than the structured tasks, and is therefore more pragmatic. Furthermore, from the usability test it becomes clear that learners identify themselves similarly with the software used in the different treatments. The experimental setting and the user interfaces were quite similar across the different treatments, resulting in a similar identification with the software. However, the average HQ-I values for the software indicate that there is still room for improvement. On the one hand, the average HQ-I values may be explained by the specific adaptation of the software to the lab scenario, which could have made the day-to-day use less apparent to or useful for the students. On the other hand, the specific language used may not have appealed to the students specifically.

Moreover, the above-average HQ-S values for the unstructured treatment groups, as opposed to the average values for the structured treatment groups, indicated that participants were stimulated more by the unstructured tasks. Thus, learners rather explore the rooms and find their own set of words for the tasks than search for a fixed list of words available in the structured tasks. In this respect, the unstructured tasks required some creativity in creating the task solution and gave the learners more opportunity to add a personal touch to their learning, which may have resulted in a higher curiosity, a higher stimulation, and higher motivation as was measured by the usability test.

Immediate performance, the Knowledge Gain

In general, no significant differences were found between treatment groups in terms of total immediate knowledge gain, KG_{total}. Table 8.2 confirms that participants had similar knowledge gains across treatments. In addition, comparisons on task type and interaction history type alone did not reveal any significant differences in the total immediate knowledge gain either. Thus, the post-test performance is similar for all participants across treatments, tasks, and history, which indicates they learnt a similar quantity of words during the learning phase.

Then again, a closer look at the categories of words learnt during the learning phase revealed that participants in the structured task groups learnt a different set of words than the participants in the unstructured task groups. On the one hand, the participants with the structured tasks focused on the words that were explicitly

given in the structured tasks; this was confirmed by the participants with the structured tasks having a significantly higher KG_{task} than those that were given the unstructured tasks. Hence, hypothesis 3a, *"the structured task treatment groups will have a significantly higher KG_{task} than those with the unstructured tasks"*, can be confirmed. On the other hand, the participants with the unstructured tasks lacked a specifically given list of words and had to find the words that were part of the task description themselves. Consequently, these participants also learnt words that were not specifically given in the structured tasks, the hidden words, which resulted in a significantly higher KG_{hidden} than the participants in the structured task groups. As a result, hypothesis 3b, *"the unstructured task treatment groups will have a significantly higher KG_{hidden} than those with the structured tasks"*, can also be confirmed.

Moreover, the effect size for KG_{hidden} was larger than that for KG_{task}. Therefore, the differences on KG_{task} are less pronounced than the differences on KG_{hidden}. While significant differences between individual treatment groups were not found for KG_{task}, the unstructured treatment groups mostly outperformed the structured ones for KG_{hidden}. This indicated that participants in the unstructured task groups also learnt words that were explicitly stated in the structured tasks. Conversely, the participants with structured tasks focused on the words that were explicitly given. The variety of words learnt is therefore larger for the unstructured task groups. As a consequence, we can conclude that participants with structured tasks had a more narrow focus on the words learnt, whereas participants with an unstructured task had a broader focus. With their more specific focus on the words explicitly mentioned in the structured task, the structured task groups learn less of the hidden words, resulting in stronger and more pronounced difference between both task types for KG_{hidden}. Indeed, mobile devices can influence the immediate focus of a learner, which results in differences in immediate knowledge gain.

Summarising, while all treatment groups learnt a similar amount of words, the structured and the unstructured groups learn differently. The groups have a different focus: whereas the structured groups are guided by the words explicitly given in the task, the unstructured groups learn a larger variety of words. As a result, the task type did not influence the amount of words learnt, but it did influence the focus and behaviour of the learner. Alternatively, the type of interaction history did not have any significant effect on any of the measured knowledge gains and therefore does not seem to have any effect on the immediate knowledge gain. The absence of an effect can be explained by the participants indicating that they rarely used the history tab. The lack of use was furthermore confirmed by the results from the logs that reveal that the history tab on average was used less than 1 minute.

Performance after one week, the Knowledge Retention and Longer-term Knowledge Gain

Significant differences have been found between the overall performance on the post-test and the retention-test, KR_{total}. The differences indicate that after an average of 9 days between post-test and retention-test, participants remembered significantly less words than right after the experiment. This result corresponds to several studies that memory decays over time (Ebbinghaus, 1964; Warrington & Sanders, 1971; Bahrick, Bahrick, & Wittlinger, 1975; Conway, Cohen, & Stanhope, 1991). A study of the retention of Spanish vocabulary over longer periods of time furthermore found that words that were learnt over spaced learning sessions were better remember than words that were learnt under massed practice (Bahrick & Phelps, 1987). In this respect, the experimental setup resembles massed practice most. All vocabulary had to be learnt in a fixed period of 40 minutes, and no option for repetition was presented in between the post-test and the retention-test. Repetition of the learning tasks over spaced intervals of time could improve retention and learning performance over longer periods of time. The importance of repetition and practice for retention has been stressed across a wide variety of topics in the theory, from automation of complex tasks (Sweller, Van Merriënboer, & Paas, 1998), to the role of private speech in second language learning (Ohta, 2001).

A significant difference between post-test and retention-test was also found for KR_{task}. In accordance with the results for KR_{total}, there is a significant decline in the number of remembered words between the post-test and the retention-test. Significant long-term effects were found for KGR_{task} and the interaction between KGR_{task} and task-type. Only the UTR treatment group had no significant increase in the number of correct answers between pre-test and retention-test, and thus has the smallest increase in words learnt. This result for the UTR treatment group influences the comparisons on task type; the structured task group outperformed the unstructured task group, but from the results it is not clear whether this effect is genuine. The effect may be a lasting one that was also found in the post-test directly after the experiment. Conversely, the UTR treatment group under-performing may also have influenced the end result of the comparison and caused the significant difference. From the results reported, no sound explanation could be found for the non-significant increase in KGR_{task} for the UTR group. Because of the UTR treatment group performing worst, it is not clear whether the significance of the interaction between KGR_{task} and task type present a genuine effect. Therefore, even if hypothesis 3c, "*the structured task treatment groups will have a significantly higher KGR_{task} than those with the unstructured tasks*", is confirmed by the results, longer-term effects on learner behaviour cannot be confirmed.

While there was a significant decline in KR_{hidden}, and thus in the number of hidden words remembered, retention was not significantly influenced by the type of treatment the participants received. No significant increase was found in KGR_{hidden}. A closer inspection reveals that only for the UTT treatment group there was a significant increase in KGR_{hidden}; all other differences were non significant. The fact that the test-differences for the STT and STR groups were non-significant can be explained by these groups (judging from table 8.2) focusing on the words described in the structured tasks; their performance on the hidden words was low in the first place. On the contrary, the UTR treatment group learnt a lot more of the hidden words, as was measured directly after the experiment, but surprisingly forgot most of them again as was indicated by KGR_{hidden}. Therefore, the influence of the task type on longer-term learner performance for the hidden words cannot be confirmed either.

Moreover, no significant effects for KGR_{hidden} have been found for task type, which could mean that the immediate effects found for the hidden words are not preserved over longer periods of time. As the UTR treatment group performs unexpectedly poor on the hidden words, it is not clear whether the absence of any longer-term effects is caused by a lack in strength of the effect on learner focus. Nonetheless, because no significant differences have been found between structured and unstructured groups, hypothesis 3d, "*the unstructured task treatment groups will have a significantly higher KGR_{hidden} than those with the structured tasks*", cannot be confirmed. Thus, in general, longer-term effects of task type on learner focus cannot be confirmed. Hypothesis 3, *"Mobile devices can influence learner focus via the learning tasks delivered",* can then be only partially confirmed, as an immediate effect on the learner focus has clearly been found, but the longer-term persistence of these effects could not be confirmed.

Overall effects

A significant decline in the number of words remembered after a longer time period was found. However, still a significant increase in the total number of correct words was found between pre-test and retention-test (KGR_{total}); this indicates a significant number of words have been remembered. Then again, the significant decline between post-test and retention-test (KR_{total}, see figure 8.9) makes it unclear how many words will be remembered over longer periods of time. Repetition by using the tool more regularly may prevent the learners from forgetting and increase the number of words remembered over time. Repeated use of the language-learning tool could also make clear the longer-term effects of different immediate learner foci. Next to repetition, presenting the language learning information in real-world

contexts, where the learning content is applied, may also result in improved retention.

No significant differences have been found between structured and unstructured treatment groups for the immediate knowledge gain. Nor, were there any significant differences in knowledge retention between different task types. Therefore, hypothesis 1, "*the participants with structured tasks will have a significantly higher immediate knowledge gain (KG) and knowledge retention (KR) than the unstructured tasks*", cannot be confirmed. Apparently, while the task type clearly affects learner focus, in general participants of both the unstructured and the structured treatment groups perform very similarly. A possible explanation for the absence of a difference between task types is that the structured and unstructured tasks did not cause that much difference in learner effort: the small differences in guidance in the tasks may have been outweighed by the effort required to find the words in the authentic environment.

No significant differences for the immediate knowledge gain were found between the time-based and room-based interaction history treatment groups. Moreover, the logged actions of the participants indicated that the interaction history was only used rarely. Any other effects on the type of interaction history can therefore be debated. It is clear then that hypothesis 2, "*the participants with time-based interaction history will significantly outperform the learners with a room-based interaction history on immediate knowledge gain (KG) and knowledge retention (KR)."*, cannot be confirmed or rejected. Quite surprisingly, the participants did not find much use in the interaction history. Possibly, the organisation of words per task provided the participants with enough support to complete the task. In addition, the time pressure for the tasks in this study was low, which could have resulted in learners not using or needing the interaction history. It would be interesting to investigate in which conditions the interaction history provides a clear benefit, as well as when such a feature would be used. Thus, to confirm hypothesis 2, more research into the effectiveness, usefulness, and use of interaction history is necessary.

Further work

Several suggestions for further work can be made based on the subsections above. First, while a clear relation between immediate learner focus and task type was found, no other effects of task type on learner performance have been found. It is therefore unclear what types of tasks are more suitable for mobile learning; more research into task structures is necessary, and could take into account results from previous studies into complex task types (Van Merriënboer, 1997; Sweller, Van

Merriënboer, & Paas, 1998; Kester, 2003; Kester, Kirschner, & Van Merriënboer, 2006). An interesting aspect to consider is the relationship between task complexity and need for additional forms of information filtering. For example, would an increase in task complexity lead to more use of interaction history view presented in this study? Especially then, more research is needed into what type of interaction history filter (location-based vs. time-based) proves more effective for which task type and what learner context.

Second, investigating real-world use of the language-learning software to support learners in accomplishing every-day tasks in a second language environment is important. Particularly, informal learning in these environments can be based on a whim, and is often not really planned. Neither will learners carry out a pre-specified list of tasks like the ones in this experiment. For learner support to be effective, a more personalised approach in which learners could add their own tasks is suggested. Moreover, for long-term retention, vocabulary should be learnt repeatedly. In the case of irregular and spontaneous learning activities, a long-term interaction history could help learners with the repetition and help them remember their previous learning activities. In addition, words learnt in a real-world context could be organised in flashcards to be used in more formal learning settings. Learners could be stimulated to learn the words they encountered in real-life settings by repetition, for example also on a mobile device. Future work could focus on how regularly words have to be repeated, in what form they could be accessed on mobile devices, and the possible use of notifications to encourage repetition. Furthermore, a social element could be added to the language software by allowing learners to access task lists and flashcards created by other learners. If the learning content is additionally enriched with location-context, the learning content, for example a list of tasks, can be narrowed down to that applicable in one setting.

Third, longer-term effects on learning have to be investigated more thoroughly. Especially, the long-term influence of learner focus was not clear in this study and should be investigated more. Moreover, the learner performance after longer periods than one week, for example after one month or two months, should be considered. In this case, the influence of repetition of the vocabulary on long-term performance is worth investigating.

CHAPTER 9
General Discussion

INTRODUCTION

In this thesis, we investigated the use of mobile devices to support the lifelong and informal learner in Learning Networks. In the first part, we analysed the current state-of-the-art in mobile social software and classified existing solutions with the reference model developed. We subsequently used the reference model to extend the existing Learning Network model with mobile learning support, and elicit technical requirements that led to the implementation of a concept framework for mobile lifelong learning. Two application scenarios were suggested to evaluate this framework. In the second part, the evaluations based on the suggested scenarios were given. Each study investigated a slightly different perspective on the main research question that was given in the introduction. In this last chapter, first a review of the results is given, that is comprised of the theoretical foundations of our work, and the empirical work done. Furthermore, the practical implications of the results presented in this thesis, are given in this section. After that, we describe the limitations of the research presented here, and conclude by giving some pointers for future research.

REVIEW OF THE RESULTS

Theoretical and technical foundations

In this thesis, we have first determined the theoretical and technical foundations for our research. In chapter 2, the current state-of-the-art in mobile social software for learning was analysed and a reference model classifying such software was developed. In chapter 3, we used the reference model to analyse and extend the Learning Networks model for social and lifelong learning. Chapter 3 also formulated technical requirements that were taken as the guidelines for a technical framework described in chapter 4. Last, two application domains were given in chapter 5, which were used in the empirical evaluation of the developed software.

In chapter 2, a review of the current state-of-the-art in mobile social software for learning was given. The review led to the formulation of a reference model that classified mobile social software for learning according to five dimensions. First, the content dimension describes the learning resources that are mostly found in the mobile learning solutions analysed. The content dimension describes applications based on the artefacts created by, exchanged by, and delivered to the learners. Content is classified into: (1) documents that contain the learning content created by and delivered to the learners, (2) annotations that contain meta-information about the other content, (3) messages that facilitate communication between learn-

ing peers, and (4) notifications, which are used to inform the user about some event of interest to their learning or to encourage the user to carry out a certain action.

Second, the context dimension describes applications based on the context parameters taken into account for learning support. The context dimension classifies the kind of contextual information used according to an operational definition of context given by Zimmermann, Lorenz, and Oppermann (2007). Five main categories of context information are specified in the reference model that can specify the context of the learner or other entities in the learning environment. Individuality context includes information about objects and users in the real world as well as information about groups and the attributes or properties the members have in common. Time context can provide information about simple points in time, but can also describe ranges, intervals, and a complete history of entities. Locations context gives the location of an entity and is divided into quantitative and qualitative location models, which allow working with absolute and relative positions. Activity context reflects the entities' goals, tasks, and actions. Relations context captures the relation an entity has established to other entities, and describes social, functional, and compositional relationships. A combination of these five context categories can be used to adapt learning support to the current context of a learner or other entity in authentic learning settings.

Third, the information flow dimension classifies applications according to the number of entities in the systems' information flow. The information flow describes the relationships between the users and other entities in the system with a ratio that relates the number of entities on either side. The following values were identified for the information flow: one-to-one, one-to-many, many-to-one, and many-to-many.

Fourth, the pedagogical model dimension identifies the pedagogical paradigms and instructional models that have been used as the main theoretical foundation for mobile learning applications. The pedagogical model dimension distinguished the behaviourist, cognitive, constructivist, and social constructivist models.

Fifth, the purpose dimension describes an application according to the goals and methods of the system for enabling learning. In our review of mobile social software for learning, we found five different purposes of mobile devices in providing learner support: sharing content and knowledge, facilitate discussion and brainstorming, social awareness, guide communication, and engagement and emersion.

With the reference model as a guideline, trends, gaps, and limitations of current research were identified in chapter 2. It was found that most mobile social software

for learning focused on sharing content between learners. On the one hand, some systems focused on sharing multimedia information. On the other hand, other systems aimed at the shared annotation of content or creation of notes. Communication between peers was not the main consideration of a lot of research, but it was mostly seen as an extension to mobile learning applications. Moreover, the use of metadata was found to be limited. While some applications used content metadata, the metadata that was used most was location context metadata. In addition, the use of notifications, to inform or motivate the learner, was not encountered often. Most often, notifications were used to inform the learner about some change in a shared context, made by a social peer. In terms of the context dimension location context and social context were found most. Other forms of context have not been used extensively. For the information flow, it became apparent that one-to-one information flows were used for direct communication and social awareness, whereas many-to-one and one-to-many were encountered mostly in formal learning scenarios, in the form of classroom response systems. Constructivist pedagogies, especially situated pedagogies, underpinned most mobile social software for learning. Mobile support for lifelong learning was seen less often. A majority of the mobile social software for learning focused on sharing content and social awareness. Mobile games were encountered least.

Based on various limitations that were found in the current state-of-the-art in mobile social software for learning, the following suggestions for improvements were made:

- provide more integrated systems with a range of functionality
- better and wider use of metadata
- more advanced and wider use of notification techniques
- an improved adaptation to the user's personal preferences and learning environment or situation by using more kinds of context information than location and identity alone, and use of techniques to derive more detailed or higher level context information by a combination of different context parameters
- more attention to systems aiming at informal and lifelong learning.

The suggestions were used as an initial guidance for our research. Moreover, the reference model provides us with a way to devise new mobile learning solutions to address the limitations, for example by extending current non-mobile e-learning applications.

In chapter 3, the suggestions for improvements to current mobile social software, found in chapter 2, were taken as a starting point to identify educational and technical requirements for a contextualised multi-platform learning framework. Chapter 3 especially focuses on informal and lifelong learning and identifies requirements

for an integrated system for mobile social learning. To this cause, the Learning Network model (Koper, & Tattersall, 2004) for social, lifelong, and informal learning is analysed and extended using the reference model for mobile social software for learning. Learning Networks are social software that support networks of lifelong learners and concentrate on supporting: (1) self-directed learning, (2) communities of practice, and (3) content creation, organisation and delivery. However, the Learning Network software aims at desktop and web-based access. Extended access with mobile devices makes more authentic forms of learning possible. Moreover, the creation of content in the real world and contextualisation of learning resources in the Learning Network makes it possible to support learning, virtually at any place and any time. With context metadata obtained from mobile device sensors, context-specific learning scenarios can be added to Learning Networks. In this sense, learning scenarios become truly lifelong and learning could be carried out across several contexts. Blended learning scenarios combining several learning contexts can be implemented using a range of technologies that all integrate the extended Learning Networks.

By mapping an existing Learning Network specification onto the reference model, technical requirements for using contextualised media in Learning Networks have been given. First, multi-platform Learning Network systems need to provide access to learning content from a wide range of devices, which requires a flexible technical infrastructure that is focused on *standardisation* and *reusability*. Second, a *modular server architecture*, in which new functionality can easily be added and integrated, increases reusability. Third, *accessibility* on different platforms calls for generic technical interfaces that make the system accessible from multiple clients. Fourth, because not all content is suitable to be displayed on all devices, the technical framework requires a certain flexibility providing *learning content filtering* and *learning content adaptation* to handle various formats and sources of learning content. Fifth, *the independence of (mobile) client technology* is important because it allows for a more heterogeneous user group and to some extent circumvents the demands of rapidly changing/aging technology. Sixth, the use of web-based content makes it possible to use *lightweight, easily portable clients* that integrate a web-browser to display the learning content, and provide device-specific software to provide access to sensors. Next to this, specialised clients could be used for educational uses with a higher demand, when high performance is needed and the strengths of the technology should be exploited. Last, the multi-platform e-learning systems should be *easy to use*. This applies to the usability of the client software, but also to the integration of the technology in existing education. One way to realise the latter, is the use of tools aimed at a specific user groups. Chapter 3 proposes at least two different user groups: on the one hand, a technical user group that manipulates and aggregates lower level information into higher-level educational concepts. On the

other hand, an educational practitioner group that uses the educational concepts defined by the first group to create sound pedagogical scenarios.

In chapter 4, the technical requirements specified are used to formulate a generic architecture for mobile social software for learning. The technical framework consists of three parts each describing a different kind of artefacts in a learning process. Each part consists of four layers that represent the forms of data used in the system; from unstructured, raw data in the lowest layer to highly structured and enriched data in the topmost layer. The context metadata and management part describes the context metadata and rules identifying the learning situation, and is based on an already existing architecture for context management that semantically enriches contextual data step by step in successive layers (Zimmermann, Lorenz, & Specht, 2005). The contextualised electronic media part handles all kinds of electronic media that constitutes the learning content used in the learning environment. Moreover, educational activities and scenarios will be modelled in this layer. The physical world objects part specifies the physical assets, relationships, and learners in a learning scenario. By combining context metadata and contextualised electronic media a technical model of the physical world can be created.

Chapter 4 moreover describes the ContextBlogger software: a client-server prototype implementation of certain parts of the technical framework. ContextBlogger combines contextualised content delivery and creation with various social software aspects like annotation, comments, and shared content. The software consists of a web portal and several types of mobile clients that can be used and adapted to a variety of learning scenarios. Chapter 5 describes two scenarios and possible application domains for mobile learning. The first scenario is a second language-learning scenario, whereas the second will portray the benefits of blended learning scenarios in a real-world building-engineering scenario. Both application domains were used in an evaluation of the ContextBlogger software, testing several types of learning in Learning Networks. The technical and educational evaluation of the software was the subject of the empirical part of our research and will be summarised in the next section.

Empirical part

In the empirical part of our research, we evaluated three different mobile learning scenarios in the application domains given in chapter 5. The scenarios served to investigate the ContextBlogger software from various technological as well as educational viewpoints. Each study measured the desirability and usability of a different software prototype and learner performance on a learning task for a specific user group. Moreover, each of the scenarios combined different aspects of the dimen-

sions in the reference model. The first study, described in chapter 6, presents a web-based software client to support adult learners in second language learning. The use of two forms of context information to adapt the learning content presented to the learner is evaluated. In addition, four selection methods, used to specify the context information in the mobile client, are compared. The second study is given in chapter 7, which evaluated a native mobile client to support university students in fieldtrips for a building engineering course. The study investigated the effect of fieldtrips supported by mobile devices on learner performance and focus. The third study, portrayed in chapter 8, looked into another second language learning scenario with secondary school students, who were supported with a fully native mobile client. Two types of authentic tasks and two types of interaction history, based on different forms of context information, were assessed in chapter 8. The results of each chapter will be discussed in more detail below.

Chapter 6 presents the first study evaluating a mobile learning application for second language learning. The study evaluated a language-learning task in which self-directed learners had to learn as many words as possible in a fixed period of time. The evaluation of the mobile language learning software took place in an artificial lab scenario with thirty-five adult learners. Six rooms of the lab were equipped with posters depicting a certain object for which the Hindi word had to be learnt. A smart phone device was used to support the learners and present them with second language content adapted to their environment. The learning content was adapted using two types of context filters that were compared on their effectiveness for the learning scenario. On the one hand, a room filter was used that filtered the vocabulary according to a more general room-location context. On the other hand, an object filter was used, which filtered the vocabulary according to a specific object-identity context. In addition, different forms of user interaction were tested for each of the context filters; four different selection methods were compared ranging from the learners specifying all context information, semi-automatic detection of the context with semacodes, to the system automatically detecting the learner context.

First, it was expected that learners using an object-filter would have a more specific interaction with the objects in their environment and therefore would have a higher knowledge gain. In contrary to our expectations, the results of the evaluation indicated that in the vocabulary learning task presented in chapter 6, learners benefit from a more generic room-location filter, which gives them an overview of all content present in the room. Second, it was expected that the selection methods which needed a fewer number of actions to access the learning content would lead to more efficient information access and therefore lead to a higher knowledge gain for the learners using them. It was found that the location-based selection method, which required least actions from the learner, outperformed all other selection

methods in terms of knowledge gain. In general, the selection methods that used room-based context information required fewer actions to access all learning content. This result was also reflected in the room-based treatment groups having higher usability ratings than the object-based groups. However, it was found that learner performance was fairly robust and independent from the selection method and context filter used. The only significant difference found was between the location-based room filter group, which performed best, and the semacode-based object filter, which performed worst of all treatments. Therefore, our expectations listed for relation between the number of actions required by the learner and the knowledge gain could not be fully confirmed. Then again, the desirability interviews with the participants revealed that semacodes were not correctly identified all the time, which lead to an increased number of actions and frustration for the participants in these treatment groups. This could explain the smaller knowledge gain for these treatment groups.

Thus, chapter 6 concluded that learner performance was quite resilient to the amount of actions performed. Moreover, we found that a more specific context information does not necessarily lead to better learner performance. Especially, in a task where learners have to learn as much of the vocabulary as possible, presenting the learner with more general information, i.e. all words for a room, is a more efficient form of learning. Hence, the learning task influences the effectiveness and efficiency of context filters. Whether the cost of accessing the learning content outweighs the benefit for the learner is also specified by the learning task. In the vocabulary-learning task in chapter 6, the time-pressure made the cost of accessing learning content outweigh the benefits in some treatment groups. To decrease the cost, the participants listed a number of improvements such as the organisation of learning content in categories and the addition of an interaction history to list all of the vocabulary looked at, in the desirability interviews.

Chapter 7 presents the second study that evaluated a mobile learning application that aims at a better integration of fieldtrips in a building engineering curriculum. The application focused on (1) preserving real-world experiences, (2) support with information resources in-situ, and (3) social support on the spot. Two groups of students were compared on their performance on a compulsory assignment in which they had to individually develop an analysis of a particular building. The classroom group could use various sources of information to gather information about buildings and construction in the classroom and at home. The fieldtrip group could use the same sources and additionally went on a fieldtrip to the chosen building to gather information in-situ. The fieldtrip group was equipped with smartphones with mobile learning software installed, which allowed them to create geo-tagged photographs of the building. In addition, photographs could be annotated with tags

identifying specific parts of the building. The students could also look at the photographs taken by their peers and leave comments for them. Because all content was uploaded to a web portal, all information in the field was also available in the classroom, creating a cross-context scenario. Eighteen students participated in the second study, who were equally and randomly distributed over the two treatment groups. Assignments were delivered in essay form and performance was measured using a rubric that laid out the specific expectations for the assignment.

The study revealed that the fieldtrip students had a significantly higher final grade for the assignments than the classroom students. More specifically, using the rubric the differences between the two treatment groups have been analysed in more detail. First, the fieldtrip students identified a significant higher number of aspects correctly than the classroom group. While no significant difference was found on the number of correctly identified general aspects, the fieldtrip group identified significantly more construction-related aspects and contextual aspects correctly. Second, the fieldtrip group also provided a significantly higher level of detail for each of the aspects than the classroom group. Again, no significant difference was found for the general aspects, but the fieldtrip group described the construction-related aspects and contextual aspects in significantly higher detail. The higher level of detail was found in both the textual description as the photographs of the fieldtrip students, which focused on specific parts of the building. Third, the fieldtrip group provided significantly more variety in the graphical information than the classroom group. A significantly higher number of photographs were included in the assignments made by the fieldtrip group. Moreover, the level of detail for the graphical information provided by the fieldtrip students was significantly higher. The results led us to conclude that the fieldtrip students had a broader and more detailed focus on the building aspects than the classroom group. An increased student motivation during the fieldtrip could have also contributed to the better performance of the fieldtrip students. In addition, the value of sharing the created learning content between the students also became clear. Students liked the social possibilities of the mobile client and portal and identified its usefulness. Furthermore, the tagging system of the software was often used to annotate detailed information of the aspects identified and students stated that the tags helped them to become aware of new building elements. Thus, the students used the social functionality of the software to share and exchange ideas and experiences while observing learning objects in the real world, which contributed to cooperation and communication.

In short, chapter 7 indicated that the developed ContextBlogger system has a variety of features that can help to pair the benefits of computer-mediated learning with direct real-world experience. First, the system supports the learner in the field and enables the student to sense and record aspects of the local environment; it

provides the opportunity to take and annotate pictures. Second, the created content is stored on a web portal, which allows later usage in classroom assignment. Last, the learners can share their own discoveries with others, supporting communication and collaboration between students. The use of such a mobile tool in building engineering courses would provide a cross-context scenario that improves the integration of fieldtrips in the curriculum, contributing to the improvement of learning.

The third study, described in chapter 8, investigated mobile learning support for another second language learning scenario with self-directed learners. The study used a similar setup as the one presented in chapter 6, but delivered the learning based on object-identity context only. In addition, a native offline client was developed that facilitated two forms of information organisation; based on an authentic task and based on the interaction history with the learning content. Chapter 8 compared two types of authentic tasks presented on a smart phone. The structured tasks presented the learners with a task description and a list of words to collect for the tasks, whereas the unstructured tasks only gave the task description. Furthermore, the study investigated two types of interaction history that presented a list of the words the learner already looked at previously. The first type of interaction history listed the words sorted chronologically (time-context). The second type of interaction history listed the words sorted alphabetically and organised by the room they were found in (location-context). Each treatment group in the originating 2x2 design was evaluated on short-term effects, directly after the experiment, as well as on longer-term effects, a week after the experiment. Furthermore, differences in learning behaviour between the groups were looked at by defining specific subcategories of the words used in the different tasks. The evaluation of the mobile language learning software was carried out with forty-four secondary school students.

First of all, chapter 8 looked at the influence of task type on learner performance. No differences in the total immediate learner performance were found between task types. Moreover, no longer-term effects of task type on learner performance were found. A possible explanation was found in the structured and unstructured tasks not causing that much difference in learner effort: the small differences in guidance in the tasks may have been outweighed by the effort required to find the words in the authentic environment. In contrast, the usability test found that participants were stimulated more by the unstructured tasks; indicating a possible preference for tasks that include more searching, creativity, and personalisation. Second, the third study investigated the influence of the interaction history type on learner performance. The participants indicated that they rarely used the interaction history, which was confirmed from the actions logged. Therefore, no immediate or longer-term effects were found on interaction history either. The lack of need for the interaction history could be explained by the organisation of words per task

providing the participants with enough support to complete the task. In addition, the time pressure for the tasks in this study was low, which could have resulted in learners not using or needing the interaction history.

Third, chapter 8 considered the influence of task type on learner focus. The learner focus was looked at by dividing the words in the task descriptions into subcategories: the first category with the words specifically stated in the structured tasks, and the second category with the words that were additionally hidden in the task descriptions. Significant differences were found for both categories in the post-test immediately after the experiment. While the structured task treatment groups performed significantly better on the first category, the unstructured task treatment groups performed significantly better on the second category. Hence, the task type used influenced the immediate learning behaviour: the structured task treatments had a more narrow focus on finding the words explicitly stated in the task, and the unstructured task treatments had a broader focus on finding any of the words in the task description. Longer-term effects of task type on learner focus could not be confirmed, however. We concluded that while the task type did not influence the amount of words learnt, it did influence the focus and behaviour of the learner. Last, a significant difference between the performance right after the test, and the performance after an average of 9 days after the experiment was found: participants remembered significantly less words after 9 days than right after the experiment. Yet, a significant increase between the number of correct answers on the pre-test and retention-test was found, indicating that the participants still knew more words than before the experiment. However, since there was already a significant decrease in the words remembered after 9 days, it is unclear how many words would be remembered over longer periods of time if no repetition took place.

Practical implications

In the introduction we argued that mobile devices provide unique opportunities for lifelong learning support. The studies presented in this thesis contributed to the field of technology-enhanced learning in general and the field of mobile learning in particular. Especially, we have investigated mobile support for lifelong learning in Learning Networks. The practical implications of the studies carried out can be summarised according to four main problems formulated as part of our general research question.

1. There is no agreed upon technical architecture for mobile lifelong learning support, nor is there a standard way of analysing, designing, and evaluating mobile social software for learning.
   a. The classification of the current state-of-the art of mobile social software can be carried out with the developed reference model that analyses mobile

learning according to five dimensions identifying both technical as educational parts.

b. The reference model provides a standard way of analysing and extending existing technology-enhanced support for lifelong and informal learning to incorporate mobile learning scenarios. To this cause an example was given in which the reference model was used to analyse Learning Networks for lifelong learning to suggest a mobile extension on the basis of a common ground with mobile social software for learning.

c. The developed concept implementation, the technical, and educational requirements can be used in and inspire future research in mobile learning. The technical and educational requirements were elicited for a technical framework for mobile lifelong learning on the basis of the Learning Network model. A concept implementation of the technical framework was developed and evaluated that incorporated several forms of learning support, both self-directed and social. During the implementation the importance of a good usability and stability of the mobile software became clear. Moreover, to keep up with the rapid developments of mobile technology, the software needs to be implemented in a flexible and extensible way, using standard software and web technology where possible.

d. Several evaluations for mobile social software for learning from both a technological as well as an educational viewpoint were carried out. We developed two application scenarios for the evaluations and evaluated usability, desirability, and educational effectiveness of the software. Evaluating mobile social software for learning from these three perspectives gave insights that helped both the scientific analysis as the technological developments of the prototypes developed. Especially, the results acquired and the rubric developed to test complex task performance can be used in future evaluations.

2. Finding and investigating the relevant design options and parameters for just-in-time information filtering and presentation.

a. To present just-in-time information to the learner, learning content adaptation should take into account more factors than context information alone. While learner performance was found to be quite resilient to the form in which the information was presented on the mobile device, bad user interaction and especially unexpected behaviour can lead to frustration and a decrease in learner performance. In addition, more specific adaption to learner context does not necessarily lead to a better learner performance. Specifically in learning scenarios with a high time-pressure it is important to present the right amount of information to the learner; too much information at once will overwhelm the learner, while too little information will

provide an additional burden in terms of increased user interaction with the software.

b. To reduce the cost of accessing learning content and increase learner performance, learning content should be organised in such a way that the demands of the authentic tasks are taken into account. The organisation of learning content can help reduce part of the time-pressure stemming from the authentic tasks. The form, effectiveness, and use of different types of learning content organisation are also mostly dictated by the authentic task. In our first study, for instance, time-pressure was high and learners suggested adding a more explicit categorisation and an interaction history to improve learning effectiveness. However, in our last study, with a low time-pressure, such an interaction history was rarely used. Therefore, presenting several additional forms of information organisation will most likely increase learner performance in authentic environments with a high time-pressure. In addition, organising learning by the authentic task performed proved to be a both effective and valued way of learning. Learners in the last study did learn effectively by organising the vocabulary according to the authentic task carried out and did not use the additional interaction history presented.

c. The presentation of content created by social peers to a learner in an authentic learning context sparks creativity, curiosity, and most likely has a positive effect on learning and motivation. Learners in the second study explicitly stated being inspired by content and annotations generated by their peers.

3. Understanding the effects of certain design factors on learning in authentic scenarios.

a. Learner performance is influenced by the authentic task at hand, the user interaction with the mobile device, and the way of filtering information according to the context of the learner. While the user interaction and context filter determine the cost of accessing the learning content, the authentic task determines the benefit associated with that cost. Mobile learning should be designed in such a way that cost and benefit are in balance: the authentic task, user interaction, and context filter should therefore not be considered in isolation. This is most illustrated by a comparison of the first study and the last study. The authentic task in the first study entailed learning as much vocabulary as possible, which made an object-identity context filter less effective because it presented only one word at a time. In contrast, in study three the authentic task entailed gathering 20 words for four different subtasks; the organisation of the words per task and the absence of time-pressure made the use of an object-identity filter a lot more effective.

b. Immediate learner focus is influenced by the task structure. In the last study we compared two types of tasks. In the first task type a list of words to be collected was presented to the learner, whereas this list was omitted for the second type of tasks. It was found that while general learning performance of both task groups did not significantly differ, the vocabulary they learnt was. Learning behaviour can thus be influenced using mobile devices.

4. Understanding the effects of embedding mobile-device-supported real-world activities in cross-context learning scenarios.

a. Learners participating in mobile-device-supported fieldtrips had a broader and more detailed focus on the learning content as opposed to learners that remained in the classroom, who focused on more general details.

b. Learners participating in real-world activities performed better on specific parts of an assignment dealing with information that is observed only or more easily in a real-world context. The authors expect tasks incorporating this kind of information to benefit from mobile learning in authentic real-world contexts.

c. Learners participating in real-world activities stated the fieldtrip and the connection they felt to social peers on the spot improved their motivation to learn.

d. For informal and lifelong learning to be effective learning experiences gathered in authentic settings should be made available for use in more formal learning contexts. Particularly, repetition of information learnt in informal learning contexts is important to make learning last; in the last study, learner performance without repetition already declined drastically within an average of 9 days.

These practical implications provide guidelines to which future research in mobile social software for lifelong learning can adhere. The authors believe the research presented will prove beneficial to the field of mobile learning in general, and to studies investigating mobile learning support for second language learning and building engineering in specific.

LIMITATIONS OF THIS RESEARCH

For the generalisation of the research presented in this thesis, several limitations of the application scenarios used, the evaluations carried out, and the software developed should be taken into account. First of all, lifelong and informal learning entails a lot of different forms of learning, of which only a small subset has been evaluated in the studies presented. Second, the studies were carried out in two application domains, second language learning and building engineering, which may have bi-

ased the final outcomes of the studies to be specific to these domains. In addition, in the experimental setups, several abstractions were made that affected the authenticity of the studied scenarios. Third, the evaluation methods may not have accounted for the full complexity of the learning scenarios studied. Last, the developed software prototypes had some limitations that may have influenced our findings. Each of these limitations will be considered in more detail in separate subsections below.

Authenticity of and transferability to other scenarios

In the introduction we set out to study mobile support for lifelong and informal learning in Learning Networks. In the experiments various aspects of mobile social software were investigated that involved making certain abstractions. Moreover, the tasks presented in the studies exhibited differences in complexity as well as differences in authenticity: the second language learning tasks mostly involved learning vocabulary not directly applied in an authentic second language environment, as opposed to the building engineering task that was concerned with the analysis of a building in the real world. Another limitation that may affect the transferability of our results can be found in the second language learning scenarios considering isolated self-directed scenarios that were not integrated into the larger communities that constitute Learning Networks. Additionally, in the building engineering study, the learner group quite small. Therefore, the results presented in this thesis should also be considered for Learning Networks of larger sizes. Furthermore, learner control and personalisation of learning was limited in most of the studies to isolate the effects investigated in the experiments. In this respect, other abstractions were also made in the authenticity of the scenarios, which may have influenced the transferability of the results to other scenarios.

On the one hand, the second language learning studies were carried out in artificial lab scenarios that minimised external influences and distractions. The absence of an authentic target language environment and the benefits and disadvantages of such an environment may affect the results in the studies. While the developed software aims at supporting real-world interaction between the learner and native speakers, especially the effect of learning content organisation and presentation on mobile devices was considered in these studies. It has to be seen if similar results can be obtained in authentic scenarios with more distractions than the lab environment. On the other hand, in the building engineering domain a lot of details can be observed in real-world contexts that cannot be easily found in classroom contexts. The results on learner focus and performance that were found in this study may therefore be not completely transferable to domains where real-world contexts play a different, less obvious role.

Limitations of the evaluation methods

A number of limitations of the evaluation methods we used in the thesis can be identified. Most of the evaluations were carried out with relatively small groups of learners that may not represent the heterogeneous community of a Learning Network well. In addition, larger learner groups would improve the generalisation of our results. A second limitation is a more general found in most studies evaluating learner performance and relates to the authenticity, validity, and reliability of the assessment tools. All of the experiments used a post-test to investigate the effectiveness of the learner. While these post-tests gave a good idea of the knowledge acquired and provided an effective tool to compare experimental conditions, they were formal tests carried out in different contexts than the authentic one. However, the successfulness of learners in authentic environments may be dictated by factors different from or additional to the ones tested in the post-tests. In our second language learning studies, for instance, the ability to portray a message to a native speaker would be more important than learning a lot of vocabulary. A real-world evaluation with native speakers could therefore reveal additional effects to the ones found in our studies. Such an authentic real-world evaluation would be influenced by a lot of additional factors and real-world interference, which would make it necessary to use observational methods instead of experimental ones. These observational methods come with problems of their own.

A third limitation of the experimental studies carried out in this thesis is that learner performance, even in tightly controlled experiments, is influenced by external factors. While some of these factors were identified in our studies, taking into account more of these external factors would increase the reliability of future evaluations. The use of desirability and usability tests already helped us isolate a number of these factors, like motivation and frustration. The extent to which they influenced learning was not clear however. In our building engineering scenario, for example, we felt the fieldtrip group was more motivated than the classroom group, but other than the comments given by the learners we had no additional evidence to substantiate this claim. Furthermore, it was not clear whether the motivational aspects stemmed from the fieldtrips, the social aspects of the software, or the use of innovative technology, or a combination of these factors. Future evaluations could be designed to isolate the effects of these factors.

Last, long-term effects were not taken into account extensively in our evaluations. Multiple evaluations over longer periods of time would give a clearer perspective on the effect of mobile support for lifelong and informal learning. Especially, the longer-term effects on learning behaviour have not become clear in the last study. Moreover, considering longer-term effects would make clear how to retain learner performance over time and help find out what happens to learner motivation if the

new-factor of the mobile technology wears off. Furthermore, the mobile devices used were no personal property and the use of it was bound to a specific time span. Extensive use of mobile devices owned by the learner may have affected learner performance and use of the software differently.

Limitations of the developed software

The developed mobile software had some limitations, which may have affected the studies presented here. The software developed was specifically aimed at testing certain assumptions that were made in the experiments. Therefore, the functionality was limited to provide the functionality under investigation. Moreover, in the period that the research in this study was carried out, mobile technology, and especially the provided software development kits, made a huge leap forward. Especially in the beginning, the development of the software was affected by problems seen in prototypical technology. Whereas in the last years the technology has matured, all software implementations were still prototypes that to some extent contained some technical problems. While in general the problems did not influence learner performance much, some prototypes caused frustration and did have a negative effect on learner performance. In addition, the adaptation to our studies, especially in the second language learning scenarios, made a real-life use less apparent, and may have influenced learners' opinions about and identification with the software. Last, the adaptation of the learning content to the learner context may have not been optimal. As we found in our first study, learner performance is subject to more factors than the location, identity, and time context used in our studies. Considering more of these factors could lead to more detailed information about the authentic situation. This in turn could lead to a better just-in-time presentation of learning content to the learner and improve support in authentic learning contexts.

FUTURE RESEARCH

In this thesis we investigated several perspectives on mobile support for lifelong and informal learning in Learning Networks. The research contributed to the emerging field of mobile learning, but also raised new questions that could be the subject of future research. Several suggestions for new research will be given in this section. First, we will provide an outlook for the developed technology, after which we give some pointers for improved evaluation methods, and possible directions for future research.

To make the ContextBlogger an integrated solution that can be applied in a variety of mobile learning scenarios, the framework should be extended. At this moment,

the ContextBlogger software already provides a shared content system in which learners can collaborate to create and edit content and view the contributions of their peers. Furthermore, ContextBlogger can create links between community-added content and real-world objects and locations. A challenge for future research would be adding social awareness in the form of ubiquitous notification support; the best timing and form of notifications has to be researched. Especially, the use of notifications to influence the learner's focus and behaviour, for example to point out people or objects of interest, deserves special attention. Moreover, the social component of the framework should be extended; while the ContextBlogger software already provided social activities like annotation, commenting, and rating, the organisation of shared content should be extended. The creation of learning communities and learning content therein should also be possible. To extend the social component of the framework we also suggest a tighter integration with existing Learning Networks software. Furthermore, to improve the adaptation of the learning content to the learner's context, the use of more complex forms of context information derived from the five basic context parameters: individuality, locations, time, environment/activity, and social/relations context, should certainly be addressed in future research. Finally, the prototypical software used in the studies was limited to the functionality tested, and still contained some problems. In future research, integrated software with a range of functionality to support the learner should be created and evaluated.

In terms of the evaluation of mobile learning support, more work should be carried out to develop evaluation methods for informal and lifelong learning in authentic settings. The studies in this thesis tested learner performance with formal evaluation methods that may not be fully applicable to learning in authentic settings, where the successfulness of learners might depend on other factors than knowledge gain. The observation of learners in authentic settings would provide some insights into these factors. On the contrary, to isolate the effects of certain forms of learner support, evaluations in experimental settings are still necessary. Therefore, future evaluations should combine experimental and observational methods to investigate the influence of mobile learning support in informal and lifelong learning. The results acquired in artificial lab scenarios with minimised external influences and distractions can then be compared with the results in the real world. In addition, to generalise the results of future research and that presented in this thesis, several suggestions can be made. First, the same forms of learner support should be evaluated in a variety of scenarios. Second, evaluations should be carried out on a larger scale, as part of larger and existing learning communities, to facilitate the heterogeneity of Learning Networks. Last, long-term evaluations should be carried out that measure learner performance over multiple points of time. On the one hand, this would give a better idea of the effect of mobile support in lifelong

learning scenarios. On the other hand, it would give a better idea of the manner and frequency in which mobile learning software is used.

In addition to improved evaluation methods, the factors that influence mobile learning in authentic contexts should be more thoroughly investigated in future research. Already some of these factors were found in this thesis, however, future research should make clear if these factors are common across scenarios more. Experiments should be designed to isolate different factors. For example, we found that task structure influences learner focus, but which types of tasks are more suitable to be used in mobile settings has not become fully clear. The influence of task complexity and structure should therefore be considered in the future. Moreover, it became clear that the effectiveness of just-in-time information presentation depends on more than context information derived from mobile device sensors alone. Different forms of context information may be useful in different scenarios; what context information is useful in which type of authentic learning scenario should also be investigated in more detail. Especially, the learning context is more than technical context information alone, and future research should take into account both the costs and the benefits of learning content access in an authentic environment, which depend on that learning context.

Finally, more research should go into informal learning support. Mobile devices are particularly suitable to support spontaneous, informal learning and help the learner to organise learning in these scenarios. In this sense, the effects of just-in-time learning content presentation should be considered. In addition, to let the learner benefit from spontaneous learning in authentic contexts, learning experiences should be preserved. Furthermore, learner performance could be improved if learning content is made available in real-world contexts. Making learning content available in multiple contexts is therefore an important point to consider. Future studies should investigate how to make learning in informal contexts a lasting experience, for example the use of repetition of learning content in creative ways. Additionally, authentic experiences can be stored for future reference, for instance, in a learning journal showing past activities. The organisation and use of past activities and experiences in other learning scenarios would improve the integration of informal learning in lifelong learning scenarios. It would be also interesting to investigate whether learning behaviour in informal contexts can be influenced with mobile devices. Additional ways of influencing the learner behaviour than the ones presented in the thesis should be looked at, as well as the longer-term effects of such techniques on learner focus and behaviour.

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Appendices

APPENDIX A:
PRE-TEST QUESTIONNAIRE FOR THE NUMBER-BASED ROOM-FILTER (NRF) TREATMENT

Welcome to our experiment. The experiment consists of three parts: first, this pre-test, then a learning phase, and finally a post-test questionnaire. Following this questionnaire you will receive an iPhone, which you will use to explore the rooms of the CELSTEC Media Lab. Login using the username and password provided below. In each room you will find some posters depicting certain objects. If you enter the current room number in the search field at the top, a selection of the pictures (tap to enlarge), the Hindi words, and Hindi audio (tap the audio icon on the right) for the objects present in the room is presented to you; learn those words and try to remember them. All your activities with the software will be logged. The results of the experiment will be handled anonymous and confidentially. Thank you for participating in this experiment. Before continuing, please first fill out your personal details below.

Personal details

Gender: ☐ Male ☐ Female
Age: ....
Occupation: ....
Treatment: roomsearchfilter

Username: ....
Password: testtest

Affinity with language learning

In this part we will ask you some general questions about the languages you speak, the level of competence in those languages, and your ability to learn new languages.

Native language:.   ....

How many *other* languages do you speak: ….....

Which other languages do you speak (0 = not at all, 4 = native speaker)?
Arabic	0	1	2	3	4
Dutch	0	1	2	3	4
English	0	1	2	3	4
French	0	1	2	3	4
German	0	1	2	3	4
Hindi-Urdu	0	1	2	3	4
Italian	0	1	2	3	4
Spanish	0	1	2	3	4
Chinese (Mandarin/Cantonese)	0	1	2	3	4

Portuguese	0	1	2	3	4
Russian	0	1	2	3	4

Other languages not mentioned ....

How well do you know Hindi?

0   1   2   3   4   (0 = not at all, 4 = native speaker)

Are you interested in learning new languages?

0   1   2   3   4   (0=not at all, 4 = very interested)

How would you estimate your ability to learn new languages?

0   1   2   3   4   (0 = not good, 4 = very good)

How would you estimate your ability to learn new languages quickly?

0   1   2   3   4   (0 = not good, 4 = very good)

Understanding of Hindi

This section will test whether you already have some knowledge of the Hindi language. Please choose the meaning for every of the Hindi words below. It is essential that you give an answer for every question; thus, if you do not know the meaning of a word, please take an 'educated guess'.

Almaari	☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Angur	☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Ainak	☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Kamal	☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Qalam	☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes

Kursee	☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Kelaa	☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Cheenee	☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Paanee	☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Namak	☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar

Nal	☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Cheh	☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pustak	☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pyaalaa	☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Mor	☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock

Magar	☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Mez	☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Lahsun	☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Seb	☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Neela	☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile

Davaa   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Haath   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Sabun   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Ungli   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Kapraa   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger

Mobile Technology & Learning

This part contains some general questions concerning the mobile technology you own, the mobile learning technology you have already used, and your opinion on using mobile technology to learn.

Do you own a mobile phone?
☐ yes ☐no

If so:
Does this phone have built-in camera?
☐ yes ☐no ☐ Don't know

How often do you use the camera?
0   1   2   3   4   (0 = never, 4 = on a daily basis)

Does this phone have built-in GPS?
☐ yes ☐no ☐ Don't know

How often do you use GPS/location-based services?
0   1   2   3   4   (0 = never, 4 = on a daily basis)

Do you own any other mobile technology?
☐ yes ☐no

If so, what kind of mobile technology?

☐ iPod   Classic   ☐iPod Touch   ☐PDA
☐ GPS receiver ☐Other Mp3-player   ☐Navigation system
☐ Other: ....
....

Did you use mobile devices for learning already?
☐ Yes (go to A) ☐ No (go to B)

Do you think mobile devices are useful for learning?
0   1   2   3   4   (0 = not useful, 4 = very useful)

A. If yes, how?
....
....
....

B. if not, would you want to use mobile devices for learning?

0   1   2   3   4   (0 = not at all, 4 = very much)

If so, any idea how?

....

....

If you think the devices to be useful, please indicate how important you think the following features, (0 = not useful, 4 = very useful)

Recording audio content for a real-world object to allow other learners to learn from a native peer
0   1   2   3   4

Listening to language podcasts recorded by a native speaker
0   1   2   3   4

Learning, creating, and reviewing flashcards, personalised lists of often used phrases, for continuous rehearsal on handhelds
0   1   2   3   4

Communication with native peers
0   1   2   3   4

Receiving language content based on your current location to support authentic language learning in the real-world
0   1   2   3   4

Receiving language content related to a real-world object, to support authentic language learning in the real-world
0   1   2   3   4

Receiving language content related to your current activity, to support authentic language learning in the real-world
0   1   2   3   4

Receiving language content based on personal preferences, interests each week
0   1   2   3   4

Using the mobile phone to translate a word anywhere & anytime
0   1   2   3   4

Receiving an SMS with the word of the day
0   1   2   3   4

Using the mobile phone as a travel dictionary with fixed categories
0   1   2   3   4

Using the mobile phone as a travel dictionary with categories based on the current context (location, time, etc.) of the learner
0   1   2   3   4

Creating/viewing pictures of your surroundings and identifying each object on the photo by adding/reading text-tags on top of the picture (as in facebook)
0   1   2   3   4

APPENDIX B: POST-TEST QUESTIONNAIRE

Thank you for participating in this experiment. In this questionnaire, we would like to ask you some questions regarding your participation in the experiment, test your understanding of Hindi, and ask you some questions about the technology and media. Last, we would like to ask you for possible improvements to the experiment. Before continuing, please again fill out your personal details below.

Personal details

Gender: ☐ Male ☐ Female
Age :   ....
Occupation: ....….................

Motivation

Did you like to participate in the experiment?

0   1   2   3   4   (0=not at all, 4 = very much)

Do you like to learn new languages?

0   1   2   3   4   (0=not at all, 4 = very much)

Did the experiment change your opinion about learning new languages?

0   1   2   3   4   (0=not at all, 4 = very much)

Would you be interested to learn more Hindi?

0   1   2   3   4   (0=not at all, 4 = very much)

How would you rate the following scenarios for language learning?

A.   Language learning software on a handheld device (for instance a mobile phone) would make it easier for me to learn a new language: 0   1   2   3   4   (0 = not easier, 4 = a lot easier) Please explain your answer above: ....
B.   Language learning software on a desktop computer would make it easier for me to learn a new language: 0   1   2   3   4   (0 = not easier, 4 = a lot easier) Please explain your answer above: . ...

Difficulty of the experiment

How often did you have problems understanding the tasks present in the experiment?

0   1   2   3   4   (0=never, 4=always)

How would you rate the difficulty of the tasks in the experiment?

0   1   2   3   4   (0=not difficult, 4=very difficult)

Understanding of Hindi

This section will test whether you gained some knowledge of the Hindi language during the learning phase. Please choose the meaning for every of the Hindi words below.

Almaari   ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Angur   ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Ainak   ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Kamal   ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Qalam   ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes

Kursee   ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Kelaa   ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Cheenee   ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Paanee   ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Namak   ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar

Nal   ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Cheh   ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pustak   ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pyaalaa   ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Mor   ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock

Magar   ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Mez   ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Lahsun   ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Seb   ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Neela   ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile

Davaa   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Haath   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Sabun   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Ungli   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Kapraa   ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger

Suitability of Technology and Media

The software was easy to understand:
0   1   2   3   4   (0 = do not agree at all, 4 = fully agree)

The objects in the pictures were clearly visible:

0   1   2   3   4   (0 = do not agree at all, 4 = fully agree)

The text was clearly visible:

0   1   2   3   4   (0 = do not agree at all, 4 = fully agree)

The audio quality was clear enough

0   1   2   3   4   (0 = do not agree at all, 4 = fully agree)

How do you estimate the benefit of mobile devices in this learning scenario?

0   1   2   3   4   (0 = not applicable, 4 =highly relevant)

Did the experiment alter your opinion about mobile devices in this learning scenario?
☐yes ☐no

Problems with the technology

Did you experience any technical problems during the experiment?
☐yes ☐no

> If so, could you please describe these problems?
> ....
> ....
> ....

Suggestions for improvements

Last, we would like to ask you suggestions, ideas or opinions for future versions of the experiment. Especially, we're interested in how you think we can improve the software to be more effective.

Were any aspects of the questionnaires unclear to you?
☐yes ☐no

> Are there any additions you would to like to see in a future version of the software?
> ....
> ....
> ....

> Any other (more general) suggestions for improvements?
> ....
> ....
> ....

If so, please elaborate so we can try to improve this in later versions:

....

....

....

Your participation in the experiment

Would you like to be informed about the results of the experiment you just participated in?
☐yes ☐no

Would you be willing to participate in a possible follow-up to this experiment?
☐yes ☐no

If you answered yes to at least one of the above questions, please fill out your e-mail address here:
....

APPENDIX C: RUBRIC FOR THE EVALUATION OF THE STUDENTS' ASSIGNMENT

Task description: "Each student will individually write an essay aimed at the identification of the main aspects and characteristics of a particular building. The assignment should include appropriate textual information and graphical information."

Table C.1.
Rubric for the evaluation of the students' assignment

DIMENSIONS	2	1	0	SCORE
EXPECTED ASPECTS (EA)				
General Aspects				
GA1 Building name	The name is correctly identified	The name is identified but has some spelling mistakes	The name is not identified or it is not correctly identified	
GA2 Functional typology	The functional typology is correctly identified and described	The functional typology is only correctly identified	The functional typology is not identified or it is not correctly identified	
GA3 Form typology	The form typology is correctly identified and described	The form typology is only correctly identified	The form typology is not identified or it is not correctly identified	
GA4 Architectural style	The architectural style is correctly identified and described	The architectural style is only correctly identified	The architectural style is not identified or it is not correctly identified	
GA5 Construction year	The construction year is correctly identified		The construction year is not identified or it is not correctly identified	
GA6 Construction cost	The construction cost is correctly identified		The construction cost is not identified or it is not correctly identified	
GA7 Building owner	The building owner's name is correctly identified	The building owner's name is identified but has some spelling mistakes	The building owner's name is not identified or it is not correctly identified	

Table C.1.
Rubric for the evaluation of the students' assignment

DIMENSIONS	2	1	0	SCORE
GA8 Architect (Architect team)	The architect's name is correctly identified	The architect's name is identified but has some spelling mistakes	The architect's name is not identified or it is not correctly identified	
GA9 History	There is an extensive paragraph about the building history (more than half page)	There is a brief paragraph about the building history (less than half page)	There isn't any paragraph about the building history or the paragraph about history doesn't belong to the building	
Construction-related aspects				
CA1 Height	The building height is correctly identified		The building height is not identified or it is not correctly identified	
CA2 Area	The building area is correctly identified		The building area is not identified or it is not correctly identified	
CA3 Floors number	The number of floors for the building is correctly identified		The number of floors for the building is not identified or it is not correctly identified	
CA4 Facilities/ spaces	The different building facilities or spaces are correctly identified and described	The different building facilities or spaces are only correctly identified	The different building facilities or spaces are not identified or they are not correctly identified	
CA5 Foundations	The foundation typology is correctly identified and different parts or characteristics are described	The foundation typology is only correctly identified	The foundation typology is not identified or it is not correctly identified	
CA6 Structure	The structure typology is correctly identified and different parts or characteristics are described	The structure typology is only correctly identified	The structure typology is not identified or it is not correctly identified	

Table C.1.
Rubric for the evaluation of the students' assignment

DIMENSIONS	2	1	0	SCORE
CA7 Roof	The roof typology is correctly identified and different parts or characteristics are described	The roof typology is only correctly identified	The roof typology is not identified or it is not correctly identified	
CA8 External walls	The external walls typology is correctly identified and different parts or characteristics are described	The external walls typology is only correctly identified	The external walls typology is not identified or it is not correctly identified	
CA9 Partitions	The partitions typology is correctly identified and different parts or characteristics are described	The partitions typology is only correctly identified	The partitions typology is not identified or it is not correctly identified	
CA10 Finishes	The finishes typologies are correctly identified and different parts or characteristics are described	The finishes typologies are only correctly identified	The finishes typologies are not identified or they are not correctly identified	
CA11 Services	The services typologies are correctly identified and different parts or characteristics are described	The services typologies are only correctly identified	The services typologies are not identified or they are not correctly identified	
CA12 Construction materials	The construction materials are correctly identified and characteristics are described	The construction materials are only correctly identified	The construction materials are not identified or they are not correctly identified	
Context-related aspects				
TA1 Location	The building location is correctly identified: the correct address is given and it is placed on a map	The building location is correctly identified: the correct address is given	The building location is not identified or it is not correctly identified	
TA2 Urban planning elements	Urban planning elements are correctly identified and described	Urban planning elements are only correctly identified	Urban planning elements are not identified or they are not correctly	

Table C.1.
Rubric for the evaluation of the students' assignment

DIMENSIONS	2	1	0	SCORE
			identified	
TA3 Environment-related aspects	Environment-related aspects are correctly identified and described	Environment-related aspects are only correctly identified	Environment-related aspects are not identified or they are not correctly identified	
TA4 Similar buildings	Similar buildings are correctly identified and similarities are described	Similar buildings are only correctly identified	Similar buildings are not identified or they are not correctly identified	
TOTAL SCORE				/50
MEDIA INFORMATION				
M1 Number of photographs	More than 10 photographs	Between 1 and 10 photographs	No photographs	
M2 Level of detail of the photographs	The photographs show the entire building and some parts of the construction	The photographs only show the entire building	There are no photographs	
M3 Number of drawings and schemas	More than 10 drawings and schemas	Between 1 and 10 drawings and schemas	No drawing nor schema	
M4 Level of detail of the drawings and schemas	The drawings and schemas represent the entire building and some parts of the construction	The drawings and schemas only represent the entire building	There are no drawings or schemas	

APPENDIX D:
T-TEST VALUES AND SIGNIFICANCE VALUES FOR EACH OF THE RUBRIC'S ASPECTS

Table D.1:

T-test values and significance values for each of the rubric's aspects

	t	p	r	Mean (*SE*)	
				Mobile (*n*=9)	Classroom (*n*=9)
General Aspect					
GA1: Name		*ns*		2.00 (.00)	2.00 (.00)
GA2: Functional typology	*t*(15.96) = -0.46	*ns*	.11	1.56 (.53)	1.67 (.50)
GA3: Form typology		*ns*		2.00 (.00)	2.00 (.00)
GA4: Architectural style	*t*(15.52) = -1.21	*ns*	.29	0.89 (1.05)	1.44 (.88)
GA5: Construction year		*ns*		2.00 (.00)	2.00 (.00)
GA6: Construction cost	*t*(16) = 0	*ns*	0	1.33 (1.00)	1.33 (1.00)
GA7: Owner	*t*(15.95) = 1.37	*ns*	.32	1.78 (.67)	1.33 (.71)
GA8: Architect (Architect team)		*ns*		2.00 (.00)	2.00 (.00)
GA9: History	*t*(15.95) = -0.34	*ns*	.08	1.22 (.67)	1.33 (.71)
Construction-related aspects					
CA1: Height	*t*(8) = 1	*ns*	.33	2.00 (.00)	1.78 (.67)
CA2: Area	*t*(9.76) = 1.58	*ns*	.45	1.89 (.33)	1.33 (1.00)
CA3: Floor number		*ns*		2.00 (.00)	2.00 (.00)
CA4: Equipment/spaces	*t*(15.46) = 1.77	*ns*	.41	1.11 (.60)	0.56 (.73)
CA5: Foundations	*t*(15.13) = -0.84	*ns*	.21	0.56 (.73)	0.89 (.93)
CA6: Structure	***t*(15.49) = 2.13**	**< .05**	**.48**	**1.67 (.50)**	**1.11 (.60)**
CA7: Roof	*t*(15.96) = 0.92	*ns*	.22	0.67 (.50)	0.44 (.53)
CA8: External walls	***t*(8) = 2.53**	**< .05**	**.67**	**2.00 (.00)**	**1.56 (.53)**
CA9: Partitions	*t*(15.59) = 1.22	*ns*	.30	0.78 (.83)	0.33 (.71)
CA10: Finishes	***t*(8) = 3.16**	**< .05**	**.75**	**0.56 (.53)**	**0.00 (.00)**
CA11: Services	*t*(12.68) = 1.25	*ns*	.33	1.56 (.53)	1.11 (.93)
CA12: Construction Materials	*t*(15.73) = 1.67	*ns*	.39	1.56 (.53)	1.11 (.60)
Context-related aspects					
TA1: Location	***t*(14.19) = 3.78**	**< .01**	**.71**	**1.67 (.50)**	**0.56 (.73)**
TA2: Urban planning elements	***t*(10.32) = 2.87**	**< .05**	**.67**	**1.89 (.33)**	**1.00 (.87)**
TA3: Environment-related aspects	***t*(15.19) = 2.75**	**< .05**	**.58**	**1.56 (.53)**	**0.78 (.67)**
TA4: Similar buildings	*t*(15.95) = 1.37	*ns*	.32	0.67 (.71)	0.22 (.67)

	t	p	r	Mean (SE)	
				Mobile (n=9)	Classroom (n=9)
Media aspects					
M1: Number of photographs	$t(16) = 4.02$	**< .001**	**.71**	**1.56 (.53)**	**0.56 (.53)**
M2: Level of detail of the photographs	$t(13.10) = 2.74$	**< .05**	**.60**	**1.67 (.50)**	**0.78 (.83)**
M3: Number of drawings and schemas	$t(16) = 1.41$	ns	.33	0.67 (.50)	0.33 (.50)
M4: Level of detail of the drawings and schemas	$t(15.53) = 1.47$	ns	.35	1.00 (.87)	0.44 (.73)

APPENDIX E:
STRUCTURED TASK DESCRIPTION

You have a busy evening coming up; after a short relaxation period at home you promised to visit your ill friend to cook her dinner, and after that you would like to attend a traditional Indian concert. Since your arrival in India last week you have been trying to learn some Hindi words. To impress your friend and also have some vocabulary available for this evening, you decide to learn some Hindi. Luckily, you have some handy language learning software on your mobile that will help you in organising the words you have to learn for each task you encounter during the day. Let's have a look at the tasks for this evening. Collect a minimum of five words for each task

Task 1

At arriving at home you decide to relax a bit before going out and make yourself a cup of spiced tea. You take some water from the tap, add the tea, and heat it. When the tea cooks you add the spices, some milk, and sugar. You fill a cup of tea and put it on a small table, and sit down in chair to read the newspaper. There's an interesting story in the newspaper about a monkey attacking tourists near the Taj Mahal. Collect a minimum of five words to perform this task.
Words: cup, tea, milk, chair, monkey

Task 2

You promised to visit your friend to bring her some medicine and fruit for the terrible cold she's caught. You take your blue car to drive up to the doctor and explain to him that you need some medicine for your friend. Explain that she has some earaches, a sore throat, and a running nose. After visiting the doctor you drive up to the market to buy some fruit, you choose some grapes, a mango, a banana, an apple, and an orange. Collect a minimum of five words to perform this task.
Words: blue, car, medicine, banana, mango

Task 3

After arriving at your friends place, you prepare an Indian meal from a cook book. The recipe says that you need one can of peas, a carrot, some chickpeas, some rice, and salt, lentils, spinach, and garlic. Furthermore, you decide to bake some bread, to go with the meal. Your friend says that you can find all ingredients in the cupboard. Collect a minimum of five words to perform this task.
Words: one, can, carrot, salt, cupboard

Task 4

You have to hurry to get in time for the concert. There's an open-air gig of a band playing some traditional Indian instruments, an Indian Drum, Sitar, and Whistle. First, you have to go home to pickup your new shoes, you forgot to bring with you. You also decided to take a woollen blanket to sit on during the concert. As part of the disaster you left the tickets at the office. You have to go up to your room to get the envelope with the tickets and some money out of your drawer. Collect a minimum of five words to perform this task.

Words: drum, whistle, money, envelope, blanket

Summary

SUMMARY

In this thesis, we explored mobile support for lifelong and informal learning. In the current knowledge-driven society it becomes more and more important for learners to manage and organise their learning in a variety of learning contexts that differ from the traditional classroom. The rise of mobile technology with increasingly complex functionality makes it possible to reach learners virtually anywhere and anytime. In addition, current mobile technology offers the ability to create and consume a wealth of multimedia content on the spot. Thus, using mobile technology, learners can access learning content in an authentic context, store and enrich real-world learning experiences for later use, and share them with peers for feedback or discussion. This unprecedented functionality creates unique possibilities to support lifelong and informal learning, some of which were considered in this thesis.

This thesis sets out to describe the focus of our research and the problems considered in chapter 1. After that, the theoretical and technical foundations were laid out in the first part of this thesis, which entails chapters 1 to 4. Two different application scenarios were given in chapter 5, which were used as an inspiration for three experimental studies in chapters 6, 7, 8. The thesis concludes with a general discussion in chapter 9 that reviews our findings, and describes the scope and the practical implications of our research. The next sections will summarise the results of this thesis.

Theoretical and technical foundations

In chapter 2, a review of the current state-of-the-art in mobile social software for learning was given. The review led to the formulation of a reference model that classified mobile social software for learning according to five dimensions: content, context, information flow, pedagogical model, and purpose. Table 1 gives an overview of all the dimensions with a range of possible values for each dimension. By combining different values from each dimension existing mobile social software can be classified. Moreover, future applications can be developed by analysing and extending non-mobile e-learning software using the dimensions in table 1.

Table 1

A reference model for mobile social software for learning

Dimension				
Content	Context	Information flow	Pedagogical model	Purpose
• Documents • Annotations • Messages • Notifications	• Individuality Context • Time Context • Locations Context • Environment or Activity Context • Relations context	• One-to-one • One-to-many • Many-to-one • Many-to-many	• Behaviourist • Cognitive • Constructivist • Social Constructivist	• Sharing Content and Knowledge • Facilitate Discussion and Brainstorming • Social Awareness • Guide Communication • Engagement and Immersion

In addition, to the classification of the current state-of-the-art in mobile social software for learning, trends, limitations, and extensions to in the current state-of-the-art were identified in chapter 1. We found that most mobile social software mainly focused on sharing content and knowledge, and that the use of context information was limited to location, identity, and social context in most systems. Based on various limitations that were found in the current state-of-the-art in mobile social software for learning, the following suggestions for improvements were made:

- provide more integrated systems with a range of functionality
- better and wider use of metadata
- more advanced and wider use of notification techniques
- an improved adaptation to the user's personal preferences and learning environment or situation by using more kinds of context information than location and identity alone, and use of techniques to derive more detailed or higher level context information by a combination of different context parameters
- more attention to systems aiming at informal and lifelong learning.

These suggestions were taken as an initial guideline to identify educational and technical requirements for a contextualised multi-platform learning framework in chapter 3. Chapter 3 especially focused on informal and lifelong learning and identifies requirements for an integrated system for mobile social learning. To this cause, the Learning Network model (Koper, & Tattersall, 2004) for social, lifelong, and informal learning was analysed and extended using the reference model for mobile social software for learning. Learning Networks support networks of lifelong learners in: (1) self-directed learning, (2) communities of practice, and (3) content creation, organisation and delivery. The described extension of Learning Networks with mobile devices makes it possible to support learning, virtually at any place and any time. More authentic forms of learning can be integrated in blended learning scenarios that combine several learning contexts found in lifelong learning.

By mapping an existing Learning Network specification onto the reference model, technical requirements for using contextualised media in Learning Networks have been given. In chapter 4, the technical requirements specified were used to formulate a generic architecture for mobile social software for learning that consists of three parts. First, the context metadata and management part describes the context metadata and rules identifying the learning situation. Second, the contextualised electronic media part handles all kinds of electronic media that constitutes the learning content and models educational activities and scenarios. Third, the physical world objects part specifies the physical assets, relationships, and learners in a learning scenario. By combining context metadata and contextualised electronic media a technical model of the physical world can be created. Chapter 4 describes a concept implementation of certain parts of the technical framework, the Context-Blogger. ContextBlogger combines contextualised content delivery and creation with various social software aspects like annotation, comments, and shared content. The software consists of a web portal and several types of mobile clients that can be used and adapted to a variety of learning scenarios. Chapter 5 describes two such scenarios and possible application domains for mobile learning. The first scenario is a second language-learning scenario, whereas the second will portray the benefits of blended learning scenarios in a real-world building-engineering scenario. The two scenarios were used as an inspiration for the empirical studies described in the next section.

Empirical findings

In the empirical part of our research, three different mobile scenarios were used to investigate the ContextBlogger software from various technological as well as educational viewpoints. Each study measured the desirability and usability of a different software prototype and learner performance on a learning task for a specific user group. Moreover, each of the scenarios combined different aspects of the dimensions in the reference model.

Chapter 6 presents the first study evaluating a mobile learning application for second language learning. The study evaluated an unbounded language-learning task in which self-directed learners had to learn as many words as possible in a fixed period of time. Two types of context filter were compared in this study: a room-based location filter, that filtered the language content according to the room the learner was located in, and object-based identity filter, which filtered the language content according to an object interacted with. Moreover, four selection methods were compared ranging from the learners specifying all context information, semi-automatic detection of the context with semacodes, to the system automatically

detecting the learner context. In contrary to our expectations, the results of the evaluation indicated that in the vocabulary learning task presented in chapter 6, learners benefit from a more generic room-location filter, which gives them an overview of all content present in the room. In addition, it was expected that the selection methods which needed a fewer number of actions to access the learning content would lead to more efficient information access and therefore lead to a higher knowledge gain for the learners using them. It was found that the fully automatic location-based selection method, which required least actions from the learner, outperformed all other selection methods in terms of knowledge gain. In general, the selection methods that used room-based context information required fewer actions to access all learning content. This result was also reflected in the room-based treatment groups having higher usability ratings than the object-based groups. However, it was found that learner performance was fairly robust and independent from the selection method and context filter used. The only significant difference found was between the location-based room filter group, which performed best, and the semacode-based object filter, which performed worst of all treatments. Therefore, our expectations listed for relation between the number of actions required by the learner and the knowledge gain could not be fully confirmed. Thus, chapter 6 found that a more specific context information does not necessarily lead to better learner performance. Especially, in a task where learners have to learn as much of the vocabulary as possible, presenting the learner with more general information, i.e. all words for a room, is a more efficient form of learning. Hence, the learning task influences the effectiveness and efficiency of context filters. Whether the cost of accessing the learning content outweighs the benefit for the learner is also specified by the learning task.

Chapter 7 presents the second study that evaluated a mobile learning application that aims at a better integration of fieldtrips in a building engineering curriculum. The application focused on (1) preserving real-world experiences, (2) support with information resources in-situ, and (3) social support on the spot. Two groups of students were compared on their performance on a compulsory assignment in which they had to individually develop an analysis of a particular building. The classroom group could use various sources of information to gather information about buildings and construction in the classroom and at home. The fieldtrip group could use the same sources and additionally went on a fieldtrip to the chosen building to gather information in-situ. The fieldtrip group was equipped with smart phones with mobile learning software installed, which allowed them to create geo-tagged photographs of the building that were stored in a shared web-portal for later access. The study revealed that the fieldtrip students had a significantly higher final grade for the assignments than the classroom students. A more detailed analysis of the assignments using a rubric revealed the following effects. First, the fieldtrip stu-

dents identified a significant higher number of aspects correctly than the classroom group. While no significant difference was found on the number of correctly identified general aspects, the fieldtrip group identified significantly more construction-related aspects and contextual aspects correctly. Second, the fieldtrip group also provided a significantly higher level of detail for the construction-related aspects and contextual aspects than the classroom group. Third, the fieldtrip group provided a significantly higher number of photographs than the classroom group. Moreover, the level of detail for the graphical information provided by the fieldtrip students was significantly higher. The results led us to conclude that the fieldtrip students had a broader and more detailed focus on the building aspects than the classroom group. An increased student motivation during the fieldtrip could have also contributed to the better performance of the fieldtrip students. In addition, the value of sharing the created learning content between the students also became clear; the students used the social functionality of the software to share and exchange ideas and experiences while observing learning objects in the real world, which contributed to cooperation and communication.

The third study, described in chapter 8, investigated mobile learning support for another second language learning scenario with self-directed learners. The study used a similar setup as the one presented in chapter 6, but delivered the learning based on object-identity context only. In addition, a native offline client was developed that facilitated two forms of information organisation; based on an authentic task and based on the interaction history with the learning content. Chapter 8 compared structured tasks, which presented the learners with a task description and a list of words to collect for the tasks, with unstructured tasks that only gave the task description. Furthermore, the study investigated two types of interaction history. The first type of interaction history listed the words accessed sorted chronologically (time-context). The second type of interaction history listed the words sorted alphabetically and organised by the room they were found in (location-context). Each treatment group in the originating 2x2 design was evaluated on short-term effects, directly after the experiment, as well as on longer-term effects, a week after the experiment. Furthermore, differences in learning behaviour between the groups were looked at by defining specific subcategories of the words used in the different tasks. First of all, chapter 8 found no influence of task type on total immediate learner performance. Moreover, no longer-term effects of task type on learner performance were found. Second, the third study revealed no immediate or longer-term effects on interaction history. This can be explained by the participants indicating that they rarely used the interaction history, which was confirmed by the actions logged. Third, chapter 8 considered the influence of task type on learner focus by dividing the words in the task descriptions into two subcategories based on the task type: the first category with the words specifically stated in the structured tasks,

and the second category with the words that were additionally hidden in the task descriptions. While the structured task treatment groups performed significantly better on the first category, the unstructured task treatment groups performed significantly better on the second category. Hence, the task type used influenced the immediate learning behaviour: it was found that the structured task treatments had a more narrow focus on finding the words explicitly stated in the task, and the unstructured task treatments has a broader focus on finding any of the words in the task description. Longer-term effects of task type on learner focus could not be confirmed, however. Last, participants remembered significantly less words after 9 days than right after the experiment. Yet, a significant increase between the number of correct answers on the pre-test and retention-test was found, indicating that the participants still knew more words than before the experiment.

Practical implications

In the introduction we argued that mobile devices provide unique opportunities for lifelong and informal learning support. The practical implications of the studies carried out can be summarised according to four main problems formulated in the introduction. Based on the theoretical analysis and empirical studies presented in this thesis, the following practical implications can be identified. First, the classification of the current state-of-the art of mobile social software can be carried out with the developed reference model that analyses mobile learning according to five dimensions identifying both technical as educational parts. Second, the reference model provides a standard way of analysing and extending existing technology-enhanced support for lifelong and informal learning to incorporate mobile learning scenarios. Third, the developed concept implementation, the technical, and educational requirements can be used in and inspire future research in mobile learning. Fourth, evaluating mobile social software for learning on desirability, usability, and educational effectiveness gave insights that helped both the scientific analysis as the technological developments of the prototypes developed. Fifth, to present just-in-time information to the learner, learning content adaptation should take into account more factors than context information alone. Sixth, to reduce the cost of accessing learning content and increase learner performance, learning content should be organised in such a way that the demands of the authentic tasks are taken into account. Seventh, the presentation of content created by social peers to a learner in an authentic learning context sparks creativity, curiosity, and most likely has a positive effect on learning and motivation. Eighth, learner performance is influenced by the authentic task at hand, the user interaction with the mobile device, and the way of filtering information according to the context of the learner. While the user interaction and context filter determine the cost of accessing the learning content, the authentic task determines the benefit associated with that

cost. Mobile learning should be designed in such a way that cost and benefit are in balance. Ninth, immediate learner focus is influenced by the task structure. It was found that while certain differences in task structure may not have an effect on general learning performance, it does have an effect on the type of learning content focused on. Learning behaviour can thus be influenced using mobile devices. Tenth, learners participating in mobile-device-supported fieldtrips had a broader and more detailed focus on the learning content as opposed to learners that remained in the classroom, who focused on more general details. Eleventh, learners participating in real-world experiences performed better on specific parts of an assignment dealing with information that is observed only or more easily in a real-world context. The authors expect tasks incorporating this kind of information to benefit from mobile learning in authentic real-world contexts. Twelfth, learners participating in real-world activties stated the fieldtrip and the connection they felt to social peers on the spot improved their motivation to learn. Last, for informal and lifelong learning to be effective learning experiences gathered in authentic settings should be made available for use in more formal learning contexts.

These practical implications provide guidelines to which future research in mobile social software for lifelong learning can adhere. Some suggestions for possible directions in future research have also been given in the general discussion. The authors believe the research presented will prove beneficial to the field of mobile learning in general, and to studies investigating mobile learning support for second language learning and building engineering in specific. However, to generalise the results presented in this thesis future work has to be carried out in other application domains with larger groups of learners. Moreover, to confirm the results, future work could combine experimental studies with observational studies in authentic real-world context. In addition, mobile lifelong learning support would benefit from long-term studies. Especially, in a society in which mobile technology plays an increasingly important role, the results of such research would become increasingly valuable.

Samenvatting

In dit proefschrift hebben we mobiele ondersteuning voor levenslang en informeel leren onderzocht. In de huidige kennisgedreven maatschappij wordt het voor lerenden steeds belangrijker om hun leren te sturen en te organiseren in een verscheidenheid van leercontexten die verschillen van het traditionele klaslokaal. De opkomst van mobiele technologie met een toenemende complexiteit aan functionaliteit maakt het mogelijk de lerenden overal en altijd te bereiken. De huidige mobiele technologie biedt tevens de mogelijkheid tot het ter plaatse creëren en consumeren van rijke multimediale inhoud. Gebruikmakend van mobiele technologie, kunnen lerenden dus leermateriaal in een authentieke leercontext bekijken, leerervaringen in de echte wereld voor later gebruik opslaan en verrijken, en deze met medestudenten delen voor terugkoppeling of een discussie. Deze nooit eerder vertoonde functionaliteit creëert dus unieke mogelijkheden voor het ondersteunen van levenslang en informeel leren, waarvan enkele werden behandeld in dit proefschrift.

Dit proefschrift begint in hoofdstuk 1 met het beschrijven van de focus van ons onderzoek en de problemen die werden behandeld. Daarna wordt de theoretische en technische basis gelegd in het eerste deel van dit proefschrift, dat de hoofdstukken 1 tot en met 4 omvat. Vervolgens worden twee verschillende toepassingsscenario's beschreven in hoofdstuk 5, die gebruikt worden als inspiratie voor de experimentele evaluaties in de hoofdstukken 6, 7, 8. Het proefschrift eindigt met de algemene discussie in hoofdstuk 9 die onze bevindingen samenvat en de strekking en praktische implicaties van ons onderzoek beschrijft. De volgende paragrafen vatten de resultaten in dit proefschrift samen.

Theoretische en technische basis

In hoofdstuk 2 wordt een kritische blik geworpen op de huidige stand van zaken in mobiele sociale leersoftware. Deze terugblik heeft geleid tot het formuleren van een referentiemodel dat mobiele sociale leersoftware classificeert aan de hand van vijf dimensies: leerinhoud, context, informatiestromen, pedagogisch model en doel. Door verschillende waarden voor elke dimensie te combineren, kan bestaande mobiele sociale leersoftware worden geclassificeerd. Verder kunnen door het gebruik van de dimensies in tabel 1, toekomstige toepassingen worden ontwikkeld door het analyseren en uitbreiden van niet-mobiele software voor elektronisch leren.

Tabel 1

Een referentiemodel voor mobiele sociale leersoftware

Dimensie				
Leerinhoud	Context	Informatiestromen	Pedagogisch model	Doel
• Documenten	• Individualeitscontext	• Eén-op-één	• Behavioristisch	• Het delen van informatie en kennis
• Annotaties	• Tijdscontext	• Eén-tot-meer	• Cognitief	• Het vergemakkelijken van Discussie en Brainstormen
• Berichten	• Locatie Context	• Meer-tot-één	• Constructivistisch	• Sociale Bewustwording
• Notificaties	• Omgevings- of Activiteitscontext	• Meer-tot-meer	• Sociaal Constructivistisch	• Het leiden van communicatie
	• Relationele context			• Enthousiasmeren en onderdompelen

Naast het classificeren van de huidige stand van zaken in mobiele sociale leersoftware, worden in hoofdstuk 1 trends, beperkingen en uitbreidingen voor de huidige oplossingen geïdentificeerd. We ontdekten dat de meeste mobiele sociale software zich vooral richt op het delen van informatie en kennis, en dat het gebruik van contextinformatie zich in de meeste systemen beperkt tot locatie-, identiteits- en sociale context. Op basis van de gevonden beperkingen in de huidige software kunnen de volgende aanbevelingen voor verbeteringen worden gemaakt:

- het verstrekken van meer geïntegreerde systemen met een groter bereik aan functionaliteit,
- beter en meer gebruik van metadata,
- geavanceerder en meer gebruik van notificatietechnieken,
- een verbeterde aanpassing aan de persoonlijke voorkeuren van de gebruiker en de leeromgeving of situatie, door gebruik te maken van meer vormen van contextinformatie dan locatie- en identiteitscontext en het gebruik van technieken om specifiekere contextinformatie of contextinformatie van een hoger niveau af te leiden door meerdere vormen van contextinformatie te combineren,
- meer aandacht voor systemen die zich richten op informeel en levenslang leren.

Deze aanbevelingen worden vervolgens gebruikt als een initiële richtlijn voor het identificeren van educatieve- en technische eisen voor multi-platform leersoftware in hoofdstuk 3. Hoofdstuk 3 richt zich daarbij vooral op informeel en levenslang leren en identificeert eisen voor een geïntegreerd systeem voor mobiel en sociaal leren. Hiervoor word allereerst het model voor leernetwerken, sociaal, levenslang en informeel leren (Koper, & Tattersall, 2004) geanalyseerd en uitgebreid door gebruik te maken van het referentiemodel voor mobiele sociale leersoftware. Leernetwerken ondersteunen netwerken van levenslang lerenden in: (1) zelfgestuurd

leren, (2) communities of practice en (3) het creëren, organiseren en aanbieden van informatie. De beschreven uitbreiding van leernetwerken met mobiele technologie maakt het mogelijk om het leren op vrijwel iedere plaats en elk tijdstip te ondersteunen. Meer authentieke vormen van leren kunnen zo worden geïntegreerd in gemengde leerscenario's die de verschillende leercontexten in het levenslang leren met elkaar combineren.

Door de bestaande specificatie voor leernetwerken op het referentiemodel te projecteren, worden technische eisen voor gecontextualiseerde media in leernetwerken afgeleid. In hoofdstuk 4 worden deze technische eisen gebruikt om een generieke, uit drie componenten bestaande, systeemarchitectuur voor mobiele sociale leersoftware af te leiden. Als eerste beschrijft het 'context metadata and management' deel de context metadata en regels die een leersituatie kunnen identificeren. Als tweede behandelt het 'contextualised electronic media' deel alle typen van elektronische media die het leermateriaal bevat. Ook modelleert dit deel de leeractiviteiten en scenario's. Als derde specificeert het 'physical world objects' deel de fysieke objecten, relaties en lerenden die deel uitmaken van een leerscenario. Door nu de context metadata en gecontextualiseerde elektronische media te combineren, kan een technisch model van de fysieke wereld geschapen worden. Hoofdstuk 4 gaat verder met het beschrijven van een conceptimplementatie van bepaalde delen van de technische systeemarchitectuur, de ContextBlogger genaamd. ContextBlogger combineert het in context aanbieden en creëren van leermateriaal met verschillende aspecten uit de social software, zoals het annoteren, het becommentariëren en het delen van informatie. De software bestaat uit een web portal en verschillende typen mobiele clients die gebruikt en aangepast kunnen worden aan een verscheidenheid van leerscenario's. Hoofdstuk 5 beschrijft twee van zulke scenario's en mogelijke toepassingsgebieden voor mobiel leren. Waar het eerste scenario het leren van een tweede taal beschrijft, wil het tweede scenario de voordelen van gemengd leren in een bouwkundig scenario in de echte wereld duidelijk maken. De twee scenario's werden gebruikt als inspiratie voor de empirische evaluaties die worden beschreven in de volgende paragraaf.

Empirische bevindingen

In het empirisch deel van ons onderzoek worden drie verschillende mobiele scenario's gebruikt om de ContextBlogger software te onderzoeken vanuit verschillende technologische en educatieve opzichten. Elk onderzoek evalueert de wenselijkheid en gebruiksvriendelijkheid van een ander software prototype en verder worden de leerprestaties voor een leertaak en specifieke gebruiksgroepen onderzocht. Bovendien combineert elk scenario verschillende aspecten van de dimensies in het referentiemodel.

Hoofdstuk 6 beschrijft het eerste onderzoek dat een mobiele applicatie voor het leren van een tweede taal evalueert. Dit onderzoek bestudeert een onbegrensde leertaak die zelfgestuurde lerenden zoveel mogelijk vocabulaire als mogelijk laat leren. Twee typen context filters worden vergeleken in dit onderzoek: een ruimte-gebaseerde locatie filter, die de woorden filtert aan de hand van de ruimte waar de lerende zich bevindt, en een objectgebaseerde identeitsfilter, die de woorden filtert aan de hand van het object dat op dat moment wordt bekeken. Daarnaast worden vier selectiemethoden vergeleken die variëren van het ingeven van alle context informatie door de lerenden, semi-automatische detectie van de context met sema-codes, tot het volledig automatisch herkennen van de leercontext. In tegenstelling tot onze verwachtingen blijkt uit de resultaten van de evaluatie dat voor het leren van vocabulaire zoals in hoofdstuk 6 gepresenteerd wordt, lerenden bevoordeeld worden door een generieke ruimte-locatie filter, die hun een overzicht van alle woorden in een ruimte geeft. We verwachtten verder dat de selectiemethoden die minder acties verlangen om het leermateriaal te bekijken, een efficiëntere informatietoegang zouden verschaffen en daarom tot een hogere kennistoename zouden leiden voor de lerenden die deze methoden gebruiken. Uit onze bevindingen blijkt dat de volledig automatische locatiegebaseerde selectiemethode, die de minste actie van de lerende verlangt, alle andere selectiemethoden op het gebied van kennistoename overtrof. In het algemeen vereisen de selectiemethoden die ruimtegebaseerde contextinformatie gebruiken minder acties om het leermateriaal te bekijken. Dit resultaat wordt ook bevestigd doordat de ruimtegebaseerde gebruikersgroepen met een hogere gebruiksvriendelijkheid gewaardeerd worden dan de objectgebaseerde groepen. Uit de resultaten blijkt echter dat de leerprestaties redelijk robuust en onafhankelijk zijn van de selectiemethode en het contextfilter. Het enige significante verschil werd gevonden tussen de locatiegebaseerde ruimtefilter-groep, die het best presteerde, en de semacode-gebaseerde objectfilter-groep, die het slechtst van alle groepen presteerde. De verwachtingen die we hadden over de relatie tussen het aantal acties uitgevoerd door de lerende enerzijds en de kennistoename anderzijds, worden niet volledig bevestigd. Uit hoofdstuk 6 bleek dus dat een specifiekere vorm van contextinformatie niet direct tot betere leerprestaties leidt. Vooral voor een taak waar lerenden zoveel mogelijk vocabulaire moeten leren, is het presenteren van generiekere informatie, dus alle woorden in een ruimte, een efficiëntere vorm van leren. We kunnen dus concluderen dat de leertaak de effectiviteit en efficiëntie van contextfilters beïnvloedt. De leertaak bepaalt ook de balans tussen de kosten van het bekijken van leermateriaal en de voordelen voor de lerende.

Hoofdstuk 7 behandelt het tweede onderzoek dat een mobiele leerapplicatie evalueert die zich richt op een betere integratie van veldwerk in een bouwkunde-

curriculum. De applicatie richt zich op (1) het behouden van ervaringen in de echte wereld, (2) het ondersteunen van lerenden met informatie in-situ, en (3) sociale ondersteuning op locatie. De prestaties van twee groepen studenten werden vergeleken aan de hand van een verplichte opdracht waarin ze individueel een analyse van een bepaald gebouw moesten ontwikkelen. De controlegroep kon, in het klaslokaal en thuis, verschillende bronnen gebruiken om informatie te verzamelen over gebouwen en constructies. De experimentele groep kon dezelfde bronnen gebruiken maar ging daarnaast nog naar het gekozen gebouw toe om informatie te verzamelen in-situ. Deze groep, die het veldwerk verrichtte, werd uitgerust met smart phones met vooraf geïnstalleerde mobiele leersoftware, die het hun mogelijk maakte om foto's van het gebouw inclusief geo-informatie te maken. De foto's werden opgeslagen in een gezamenlijke web-portal zodat deze later gebruikt konden worden. Het onderzoek onthult dat de studenten die het veldwerk verrichtten een significant hoger punt hadden voor hun opdrachten dan de andere groep. Door een gedetailleerdere analyse van de opdrachten met gebruik van een rubriek zijn de volgende effecten duidelijk geworden. Als eerste identificeerden de studenten die het veldwerk verrichtten een significant groter aantal aspecten correct dan de andere groep. Terwijl er geen significant verschil gevonden werd bij het aantal correct geïdentificeerde algemene aspecten, werd er door de groep met het veldwerk wel een significant groter aantal constructiegerelateerde en contextuele aspecten correct geïdentificeerd. Ten tweede verschafte de groep met het veldwerk een significant hoger detailniveau voor de constructiegerelateerde aspecten en de contextuele aspecten. Ten derde werd er door de groep met het veldwerk ook een significant groter aantal foto's aangeleverd. Daarnaast was het detailniveau van de aangeleverde grafische informatie ook significant hoger voor de studenten met het veldwerk. De resultaten leiden tot de conclusie dat de studenten met het veldwerk een bredere en een gedetailleerdere focus op de constructieaspecten hadden dan de andere groep studenten. Een hogere motivatie gedurende het veldwerk kan hebben bijgedragen aan deze betere prestaties. De toegevoegde waarde van het delen van het gecreëerde leermateriaal tussen de studenten werd eveneens duidelijk; de studenten gebruikten de sociale functionaliteit van de software om ideeën en de ervaringen tijdens het observeren van leerobjecten in de echte wereld te delen, wat bijdroeg aan samenwerking en communicatie.

Het derde onderzoek, dat in hoofdstuk 8 beschreven wordt, onderzoekt ondersteuning voor mobiel leren van zelfgestuurde lerenden voor een ander scenario voor het leren van een tweede taal. Dit onderzoek heeft eenzelfde opzet als dat, dat in hoofdstuk 6 gepresenteerd werd, maar biedt het leermateriaal alleen op basis van object-identiteitscontext aan. Verder word er een 'native offline client' beschreven die twee vormen van informatieorganisatie mogelijk maakt; enerzijds gebaseerd op een authentieke taak en anderzijds op de interactiegeschiedenis met het leermate-

riaal. Hoofdstuk 8 vergelijkt gestructureerde taken, die lerenden een taakbeschrijving geven en een lijst met woorden die voor deze taken verzameld moeten worden, en ongestructureerde taken die volstaan met een taakbeschrijving. Daarnaast worden er twee typen interactiegeschiedenis onderzocht. Het eerste type interactiegeschiedenis geeft de bekeken woorden in een chronologisch geordende lijst (tijdscontext). Het tweede type interactiegeschiedenis sorteert de woorden op alfabetische volgorde en organiseert ze per ruimte (locatie context). Elke groep in het 2x2 ontwerp wordt geëvalueerd op kortetermijneffecten, die gemeten worden direct na het experiment, alsook op langetermijneffecten, een week na het experiment. Ook wordt nog gekeken naar verschillen in leergedrag tussen de groepen, door het definiëren van specifieke subcategorieën van de woorden die in de taken gebruikt worden. Allereerst is er in hoofdstuk 8 geen relatie tussen taaktype en de totale directe leerprestatie gevonden. Ook zijn er geen langetermijneffecten van taaktype op de leerprestatie gevonden. Ten tweede onthult het derde experiment geen directe of langetermijneffecten van de interactiegeschiedenis. Dit kan worden uitgelegd doordat de deelnemers aan het experiment aangaven dat ze de interactiegeschiedenis zelden gebruikten, wat ook nog werd bevestigd door de gelogde acties. Ten derde bekijkt hoofdstuk 8 de invloed van taaktype op leerfocus door de woorden in de taakbeschrijving in twee subcategorieën te verdelen die gebaseerd zijn op het taaktype: de eerste categorie woorden omvat alle woorden die specifiek genoemd werden in de gestructureerde taken, de tweede categorie bestaat uit de woorden die daarnaast nog in de taakbeschrijvingen zijn verborgen. Het werd duidelijk dat terwijl de groepen met de gestructureerde taken significant beter presteerden op de eerste categorie woorden, de groepen met de ongestructureerde taken significant beter presteerden op de tweede categorie. We kunnen dus concluderen dat het gebruikte taaktype het directe leergedrag beïnvloedt: het werd duidelijk dat de groepen met de gestructureerde taken een specifiekere focus hadden op het vinden van de woorden die expliciet in de taken genoemd werden, terwijl de groepen met de ongestructureerde taken een bredere focus hadden op het vinden van welk woord in de taakbeschrijving dan ook. Langetermijneffecten van taaktype op leerfocus konden niet worden bevestigd. Als laatste onthielden de deelnemers significant minder woorden na 9 dagen dan meteen na het experiment. Maar er werd nog steeds een significante toename in het aantal correcte antwoorden tussen pre-test en retentie-test gevonden. Dit geeft aan dat de deelnemers nog steeds meer woorden wisten dan voor het experiment.

Praktische implicaties

In de introductie beargumenteerden we dat mobiele technologie unieke mogelijkheden voor het ondersteunen van levenslang en informeel leren biedt. De praktische implicaties van het uitgevoerde onderzoek kan worden samengevat in relatie

tot de vier hoofdproblemen die geformuleerd werden in de introductie. Op basis van de theoretische analyse en de empirische evaluaties in dit proefschrift kunnen de volgende praktische implicaties worden geïdentificeerd. Ten eerste, de classificatie van de huidige stand van zaken in mobiele sociale leersoftware kan uitgevoerd worden met behulp van het ontwikkelde referentiemodel dat mobiel leren analyseert aan de hand van vijf dimensies, die zowel technische als educatieve delen identificeren. Ten tweede geeft het referentiemodel een standaardmanier om bestaande technologie voor levenslang en informeel leren te analyseren en uit te breiden met scenario's voor mobiel leren. Ten derde kunnen de ontwikkelde conceptimplementatie, de technische en educatieve eisen gebruikt worden in toekomstig onderzoek of dit onderzoek naar mobiel leren inspireren. Ten vierde geeft het evalueren van mobiele sociale leersoftware op wenselijkheid, gebruiksvriendelijkheid en educatieve effectiviteit inzichten die zowel de wetenschappelijke studie als de technologische ontwikkeling van de ontwikkelde prototypes helpen. Ten vijfde, om informatie op het juiste moment aan de lerende aan te bieden, moet het leermateriaal aangepast worden aan meer factoren dan alleen de leercontext. Ten zesde, om de kosten van het bekijken van leermateriaal te beperken en leerprestaties te bevorderen moet het leermateriaal zo georganiseerd worden dat de eisen van de authentieke taken in acht genomen worden. Ten zevende, het aanbieden van leermateriaal, dat gecreëerd is door medestudenten aan een lerende in een authentieke leercontext veroorzaakt creativiteit, nieuwsgierigheid en heeft hoogstwaarschijnlijk een positief effect op het leren en de motivatie. Ten achtste wordt de leerprestatie beïnvloed door de authentieke taak, de interactie van de gebruiker met de mobiele technologie en de manier waarop informatie wordt gefilterd ten opzichte van de leercontext. Terwijl de gebruikersinteractie en de context filter de kosten van het bekijken van het leermateriaal bepalen, bepaalt de authentieke taak het voordeel dat met die kosten geassocieerd wordt. Mobiel leren zou dan ook zo ontworpen moeten worden dat de kosten en de voordelen met elkaar in balans zijn. Ten negende wordt de directe leerfocus beïnvloed door de taakstructuur. We vonden dat, terwijl bepaalde verschillen in taakstructuur geen effect kunnen hebben op de algemene leerprestatie, ze wel een effect kunnen hebben op de focus op het leermateriaal. Leergedrag kan dus beïnvloed worden door mobiele technologie. Ten tiende hebben lerenden die deelnemen aan veldwerk dat door mobiele technologie ondersteund wordt, een bredere en meer specifiekere focus op het leermateriaal. Dit in tegenstelling tot lerenden die in het klaslokaal blijven en zich daardoor meer op algemene details richten. Ten elfde presteren lerenden die deelnemen aan ervaringen in de echte wereld beter op die delen van een opdracht die over informatie gaan die alleen of makkelijker gevonden kan worden in een authentieke context. De auteurs verwachten dat vooral taken waarin dit soort informatie aan bod komt, zullen profiteren van mobiel leren in een authentieke echte wereldcontext. Ten twaalfde geven lerenden die in echte wereldactiviteiten deelnamen aan dat het

veldwerk en de verbinding die ze ter plaatse voelen met medestudenten, bijdraagt aan hun motivatie om te leren. Als laatste moet informeel en levenslang leren om effectief te zijn, ervaringen die verzameld zijn in een authentieke context beschikbaar maken voor het gebruik in meer formele situaties.

Deze praktische implicaties zorgen voor richtlijnen die bij toekomstig onderzoek naar mobiele sociale software voor levenslang leren gevolgd kunnen worden. In de algemene discussie worden een aantal suggesties voor toekomstig onderzoek gegeven. De auteurs verwachten dat het beschreven onderzoek een positieve bijdrage zal leveren aan het onderzoek naar mobiel leren in het algemeen, en aan onderzoek naar mobiele ondersteuning voor het leren van een tweede taal en bouwkunde in het bijzonder. Meer onderzoek zal echter in de toekomst nodig zijn om de resultaten in dit proefschrift verder te generaliseren. Onder andere zullen door dit onderzoek andere applicatiedomeinen onderzocht moeten worden met grotere groepen lerenden. Daarnaast zal toekomstig onderzoek, om de resultaten te bekrachtigen, experimenteel met observationeel onderzoek in een authentieke context kunnen combineren. Ook zou het onderzoek naar het mobiel ondersteunen van levenslang leren kunnen profiteren van langetermijnevaluaties. Vooral in een maatschappij waar mobiele technologie een steeds belangrijkere rol speelt zullen de resultaten van dit soort onderzoek steeds waardevoller worden.

Curriculum Vitae

CURRICULUM VITAE

Tim De Jong was born on the 11th of December 1981 in Heerlen, the Netherlands. He studied knowledge engineering at the University of Maastricht, and successfully finished these studies with a Master's degree in artificial intelligence in May 2005. For a short period in the beginning of 2006, Tim worked as a software engineer at the General Statistics Bureau (CBS) of the Ministry of Economic Affairs in the Netherlands.

In April 2006, Tim started his academic career in technology-enhanced learning, when he joined the Open University of the Netherlands. He started off in the European funded Integrated Project TENCompetence (6th Framework Programme) and later continued in the European eContentPlus project MACE. Tim has 11 publications in the field of technology-enhanced learning and he served as a reviewer and programme committee member for international conferences, journals, and books. Tim is currently working as a software engineer at Maastricht Instruments and the IDEE service of the Maastricht University.

PHD-RELATED PUBLICATIONS AND ACTIVITIES

Scientific publications

De Jong, T., Specht, M., & Koper, R. (2008). A Reference Model for Mobile Social Software for Learning. *International Journal of Continuing Engineering Education and Life-Long Learning (IJCEELL). 18*(1), 118–138.

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Programme committee membership

Mobile Learning 2009, IADIS International Conference 2009. February 26–28, 2009, Barcelona, Spain.

Mobile Learning 2008, IADIS International Conference 2008. April 11–13, 2008, Algarve, Portugal.

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Review activities

Digitel 2010, The 3rd IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, April 12–16, 2010, Kaohsiung, Taiwan.

STELLAR Alpine Rendez-Vous 2009, November 30 – December 3, 2009, Garmisch-Partenkirchen, Germany.

ICCE 2008, 16th International Conference on Computers in Education. October 27–31, 2008, Taipei, Taiwan.

AH 2008, The 5th International Conference on Adaptive Hypermedia and Adaptive Web based Systems, 29 July – 01 August, Hannover, Germany.

eLBa 2008, International Scientific E-learning Conference, June 18–19, 2008, Rostock, Germany.

TSSOL 2008, 1st Workshop on Technology Support for Self-Organised Learners, June 2–3, 2008, Salzburg, Austria.

ICALT 2007, The 7th IEEE International Conference on Advanced Learning Technologies: Learning technologies in the Information society, July 18–20, 2007, Niigata, Japan.

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SIKS Dissertatiereeks

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