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Innovation in Mobile Learning: a European Perspective

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Abstract

In the evolving landscape of mobile learning, European researchers have conducted significant mobile learning projects, representing a distinct perspective on mobile learning research and development. Our paper aims to explore how these projects have arisen, showing the driving forces of European innovation in mobile learning. We propose context as a central construct in mobile learning and examine theories of learning for the mobile world, based on physical, technological, conceptual, social and temporal mobility. We also examine the impacts of mobile learning research on educational practices and the implications for policy. Throughout, we identify lessons learnt from European experiences to date.

Keywords: Europe, innovation, research projects, context, collaboration, interaction design, learning theory

Introduction

The proliferation of mobile phones and other handheld devices has transformed mobile learning from a researcher-led, specialist endeavour, to an everyday activity where mobile devices are personal tools helping people learn wherever they go, through formal training or informal support and conversation (Kukulska-Hulme et al., 2007). Even so, the effective design and development of mobile learning applications and experiences, and their evaluation, are still core activities where specialist expertise, and the initiatives and insights of teachers and learners, have important roles to play. From our perspective as researchers based in Europe, we consider it valuable to highlight and synthesize the innovative design, development and evaluation practices that have characterised European projects over the past several years. We see this as a step towards building up a more detailed picture of how the field of mobile learning is developing in various parts of the world, given that motivations and conditions are often very different (Rao & Mendoza, 2005).

Our expertise in mobile learning includes management of the European Mobile Learning Special Interest Group and leadership of projects including HandLeR (Sharples, 2000; Sharples, Corlett & Westmancott, 2002), MOBILearn (Lonsdale et al., 2004), Mobile Learning Organiser (Corlett et al., 2005), Caerus (Naismith, Sharples & Ting, 2005), Case Studies in Innovative e-Learning Practice (Kukulska-Hulme et al., 2005b), Mobile Learning Landscape Study (Kukulska-Hulme et al., 2005a), Myartspace (Sharples et al. 2007a; Vavoula et al. 2007), Personal Inquiry (Anastopoulou et al., 2008), MUSIS (Milrad & Jackson, 2008), the Treasure Hunt (Spikol & Milrad, 2008), AMULETS (Kurti et al., 2008), and The mobileDNA (Arnedillo-Sánchez, 2008; Byrne, Arnedillo-Sánchez & Tangney, 2008).

As mobile learning continues to challenge the boundaries imposed by traditional classroom learning, it raises questions about its significance in relation to wider ambitions to improve education and exploit technology in furthering that aim. What shifts in pedagogical and theoretical perspectives have been observed? To what extent are e-learning policy and initiatives taking account of research project results and the potential of mobile learning? We examine the evidence, and highlight issues and barriers to more widespread uptake, such as provision of teacher training. Throughout

the paper, we identify more general lessons learnt from European mobile learning R&D to date. Although rooted in European research, the particular ways of thinking about technology, design or evaluation, may be transferable elsewhere – we leave it to other researchers and practitioners to make those judgments.

The paper starts with a review of five projects that have shaped research and development of mobile learning in Europe: HandLeR, MOBILearn, M-Learning; and two projects funded under the Leonardo da Vinci Programme. These projects were not only influential in demonstrating the value of mobile technology for learning, they also provided an opportunity to devise and debate theoretical foundations for a new pedagogy and practice of mobile learning, outlined in the next section. A change in emphasis, away from design of educational software for portable devices and towards socio-technical support for the mobility of learners, led to a more expansive framework for mobile learning and a set of innovative projects across a wide range of physical, institutional and social settings. The section entitled 'Recent Mobile Learning Projects' presents a representative selection of these projects, organised by the setting of the learning. Having indicated the scope of current European research into mobile learning, the Discussion section indicates findings from the projects in relation to designs for learning with personal technologies across contexts. Future success of mobile learning in school settings will depend on the preparedness of teachers to adopt mobile technologies in the classroom. In the section on 'Teacher Development' we discuss the relations between research, practice and policy, including the implications for teacher training and development. Taking a broader perspective, the impact of mobile learning in Europe has both shaped and been formed by national and European policy and this is discussed in a section on Education Policy for Mobile Learning. A concluding section suggests future challenges for researchers, developers and policy makers in shaping the future of mobile learning.

Foundational European Mobile Learning Projects

Computer-supported mobile learning in Europe has a history that stretches back to the 1980s when early handheld devices were trialled in a few schools, such as the Microwriter (a handheld writing device with a unique chord keyboard comprising one button for each finger and two for the thumb that could be pressed in combinations to produce characters on a single line display) and the Psion handheld computer. Although later versions of the Psion computer were more widely adopted (Perry, 2003) they were mainly restricted to classroom use for the teaching of English (High & Fox, 1984). A broader perspective on mobile learning arose in the mid 1990s with research projects to exploit a new generation of pen tablet and Personal Digital Assistant (PDA) devices for learning. In this section, we assess the contribution of several European projects that have shaped developments in mobile learning.

HandLeR

One early project was HandLeR (Handheld Learning Resource) from the University of Birmingham (Sharples, 2000; Sharples, Corlett & Westmancott, 2002). The project started in 1998 as an assignment for a group of electronic engineering students to revisit the seminal Dynabook concept of the early 1970s and develop "a portable interactive personal computer, as accessible as a book" (Kay & Goldberg, 1977). HandLeR was based on a theory of learning as conversation (Pask, 1976) instantiated through a set of scenarios including an 11 year old child on a school field trip, a radiologist in her first year of specialist training in neuroradiology, and a senior citizen recalling and organising a lifetime of memories. Figure 1 shows design concepts of a HandLeR device for children and adults. The school field trip scenario was then realised in the design of a handheld device that combined a tablet computer, camera, wireless and mobile phone connection.

Figure 1. Mockups of the HandLeR concept for children and adults

The project addressed issues of user interface design for mobile learning. The software for the field trip HandLeR was developed through interviews and questionnaires with children aged 11-12 to create a style of interaction that was more appropriate to children learning in the field than the office-bound 'desktop' interface. Through design discussions, the team produced an interface based on the notion of an animate 'mentor' that could act both as a learning guide and a means of interaction. In the interface, clicking on body parts launches tools, such as the eyes for a camera, hands for a writing pad, and brain for a concept mapping tool. Figure 2 shows the main HandLeR screen and the concept mapping interface. The concept map provided a general tool to view and browse information.

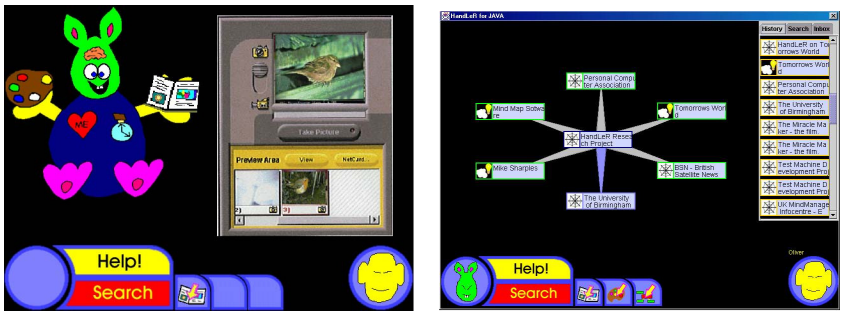

Figure 2a & 2b. Main screen and concept mapping tool from the HandLeR children's field trip interface

Whenever a photo is taken, note made, or web page accessed, this is shown in a timeline on the concept map (shown at the right of Figure 2b). An item in the timeline can be dragged and attached to the concept map. To browse through the map the user clicks a node (box) on one of the outer links which moves it to the centre of the map and displays its connected nodes. Clicking on a central node opens the resource (photo, note, drawing, web page) associated with it. This interface proved to be an easy and powerful way to view and link items created in the field. The 'avatar' interface (Figure 2a), was less successful. Although children liked the idea of an animate mentor, the relations between parts of the body and tools were not clear and, most important, the children regarded a cartoon rabbit as 'childish'. A mentor in the shape of a TV character or sports star might have been more successful.

An important conclusion from trials of the HandLeR system was that the technology at that time had severe limitations which made it almost impossible to use. Handwriting recognition on the computer developed for HandLeR (a Fujitsu Stylistic LT) was poor, the battery life was limited to one hour, and the weight of 1.5 kg meant the device had to be balanced on a flat surface or knee for operation. The main success of the HandLeR project was to establish the concept of mobile and contextual learning outside the classroom, for field trips and professional development. It developed general

requirements for technologies to support contextual life-long learning (Sharples, 2000) that have been adopted by some later projects. Such technologies should be:

- *highly portable*, so that they can be available wherever the user needs to learn;
- *individual*, adapting to the learner's abilities, knowledge and learning styles and designed to support personal learning, rather than general office work;
- *unobtrusive*, so that the learner can capture situations and retrieve knowledge without the technology obtruding on the situation;
- *available* anywhere, to enable communication with teachers, experts and peers;
- *adaptable* to the context of learning and the learner's evolving skills and knowledge;
- *persistent*, to manage learning throughout a lifetime, so that the learner's personal accumulation of resources and knowledge will be immediately accessible despite changes in technology;
- *useful*, suited to everyday needs for communication, reference, work and learning;
- *easy to use* by people with no previous experience of the technology.

Some of these requirements, particularly learner adaptivity, have yet to be fully realised, while further ones have become prominent, notably support for collaboration and teamwork.

The University of Birmingham, where the HandLeR project originated, hosted the first international conference on mobile and contextual learning in June 2002 (http://www.eee.bham.ac.uk/mlearn/), which led to the international mLearn conference series. Also in 2002, the First IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2002) took place at Växjö University in Sweden (http://lttf.ieee.org/wmte2002/). This event led to the series of international conferences held in Asia and in Europe in the field of mobile learning.

In 2001-2, the Fifth Framework research programme of the European Commission funded two major research projects, MOBIlearn and m-Learning. Along with the 'From e-Learning to m-Learning' project funded under the Leonardo da Vinci Community vocational training action programme, these established the scope and direction of mobile learning across Europe. The main contributions of these projects are outlined below.

MOBILearn

MOBIlearn was a European-led research and development project that ran for 33 months from January 2002 to March 2005 and involved 24 partners from academia and industry in ten countries (www.mobilearn.org). Its aim was to develop, implement, and evaluate an architecture for mobile learning, based on theories of effective teaching and learning in a mobile environment. The focus of the project was to develop and support learning outside the classroom, including learning in museums, studying for a work-related MBA, and gaining basic medical knowledge.

The ambition of MOBIlearn was broad: to provide ubiquitous access to knowledge for target users including mobile workers and learning citizens through appropriate (contextualized and personalized) learning objects and innovative mobile services and interfaces. It proposed to develop new models of learning in a mobile environment, new systems architectures to support the creation, delivery and tracking of learning content, new methods to adapt learning materials to mobile devices and new business models for sustainable deployment of mobile technologies for learning.

One key product of MOBIlearn was a general architecture for interoperable services (Figure 3), the "Open Mobile Access Abstract Framework" (OMAF) (Da Bormida et al., 2003). This provided generic services, such as user registration and messaging, management of content, and specific tools for mobile interaction and context

awareness. The services could be distributed across the web and were accessed through a portal that adapted to mobile devices including mobile phones, PDAs and tablet computers.

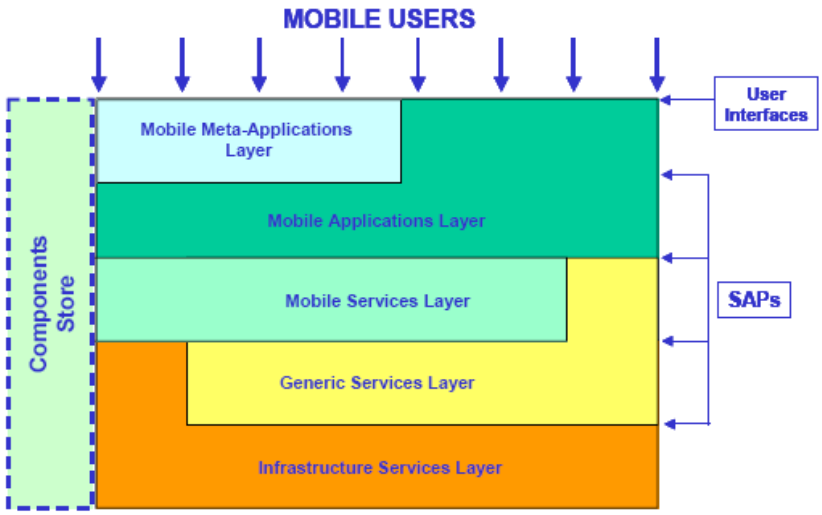

Figure 3. MOBIlearn Open Mobile Access Abstract Framework

The MOBIlearn system was implemented and tested with three scenarios designed to cover a space of non-formal learning events that were either initiated by the learner or an education institution, and either personally or externally structured (Figure 4). The detailed scenarios were developed through a series of design workshops with researchers and stakeholders and are summarised below:

Museum: Two art history students visiting a museum to learn about the works of Boticelli.
First Aid: A leader of a workplace First Aid team, running a practical course for the team on emergency First Aid procedures.
Campus-based: Students on an MBA course learning about the university on first-week orientation course and then carrying out a team business administration project in their workplaces.

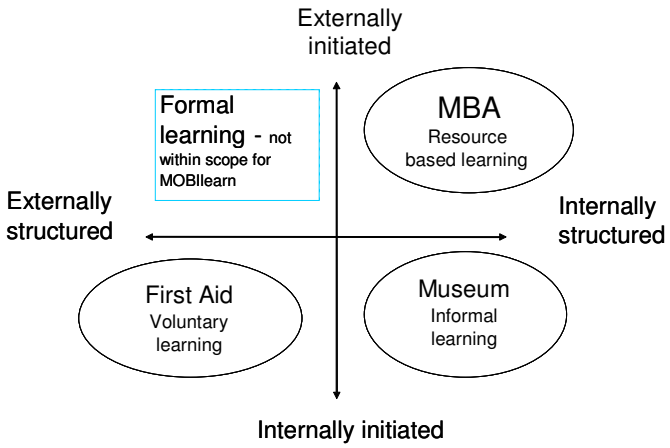

Figure 4. Types of learning (adapted from Livingstone, 2001).

Each of the scenarios was tested with elements of the MOBIlearn technology, though the museum one was most fully explored. The system was tested with representative

users at the Uffizi Gallery in Florence, with further trials of the context awareness system at the Nottingham Castle Museum and gallery in Nottingham, UK. The trials were successful in demonstrating that people could interact with the technology in a museum setting, and that the context-awareness system could provide information and guidance depending on the users' location, route, and time at the location. The trials also indicated a number of issues including the importance of offering *variety* in content and ways to perform a task, opportunities for *synchronizing* activity through messages and prompts about the location of other users, the value of *spatial movement* as a way to interact with a mobile system (for example, the user moving from one painting to another, or waiting in front of an exhibit could be used by the system to infer their knowledge or interest) and the need to develop a *simple* and *coherent* interface across a variety of devices.

The aims of the project were met to the extent that it established the viability of handheld technology to support context-sensitive learning in non-formal settings. The lead partner, Giunti Labs has developed a mobile extension to its Learn eXact system based on results from Mobilearn and two other European projects: wearIT@work[1] and iTutor[2]. A broader consequence of the MOBIlearn project was a shift in focus from learning with handheld devices, towards support for the mobility of learning. A mobile learner may interact with a variety of fixed and portable technologies and a central challenge is to connect the learning across contexts and life transitions. Another outcome of the project was to develop a theory of learning for the mobile age, that explores the system of learning enabled by mobility of people and technology and identifies distinctive aspects of mobile learning, including the distribution of learning across contexts, and the artful creation of impromptu sites for learning involving technology, people and settings (Sharples, Taylor & Vavoula, 2007).

M-Learning

Like MOBIlearn, the M-Learning project was funded by the European Fifth Framework programme, but its aims were different: to help young adults aged 16 to 24, who were disaffected learners and had not succeeded in the education system. The UK Learning and Skills Development Agency (LSDA) coordinated the project, and participant organisations included universities and commercial companies based in the UK, Italy and Sweden (m-Learning, 2005).

The project developed a Learning Management System and a microportal interface to provide access to learning materials and services from a variety of mobile devices, plus web and TV access. Example applications included an authoring system to create and deliver SMS quizzes for topics such as health information and drugs advice, mobile phone games, for example to allow learner drivers to practise driving theory questions, and a media board for learners to build online web pages by sending messages, pictures and audio from their phones.

Reports from the project concluded that mobile learning *can work*, reaching places that other learning cannot, it is best provided as part of a *blend* of learning activities, it offers a *collection of pieces* to be fitted to a learning need rather than a single solution, it is not simply a tool for delivering teaching material but can be used for learning through *creativity*, *collaboration* and *communication*, and that the best way to get started with developing mobile learning is *to try it in practice* through trial and experiment with simple tools.

From e-Learning to m-Learning and *Mobile Learning: The Next Generation of Learning*

The European Commission has funded mobile learning projects under its Leonardo da Vinci Programme, with the aim to support vocational education and training using mobile phones for delivery of learning content (see also Sampson, 2006). Two related projects were led by Ericsson. The first, 'From e-Learning to m-Learning', designed pedagogical scenarios, developed courses and trialled them with students using both

PDAs and mobile phones. The more recent project developed learning materials for the new generation of devices that offer email, web-browsing capabilities, streaming audio and video and multimedia messaging (Ericsson, 2008). Both projects were somewhat different to the others reported in this paper, in their focus on delivery of content to mobile devices for training.

A report on the projects indicated that the earlier one solved most of the problems of presenting courses on PDAs, employing Microsoft Reader Works to provide a pleasant study environment (Nix, 2005). This comprised 1000 A4 pages, which could be easily held by the 128 MB of memory of a HP Compaq iPac 5500. The successor project has developed a set of multimedia technologies for delivering interactive content to mobile devices including XHTML 1.0 Transitional, Cascading Style Sheets (CSS) levels 1 & 2, Java Script and Document Object Model (DOM).

A trial was carried out to deliver a course with technical learning content to nineteen Ericsson staff using Sony Ericsson P900 phones. It found that students were positive about the user-friendliness of the mobile devices and m-learning in general and over half of the participants (56%) agreed that the experience was fun. However, only 45% of the participants were in agreement that m-learning increases the quality of e-learning. The report describes technical difficulties that meant the expectations of participants were not always met:

> Having to reconnect to the network frequently caused some frustration even though the decisions taken on how to design and develop the course led to improved download times, display of content and navigation experience. Those students who experienced difficulty with the size of the screen and other physical limitations felt that the mLearning course did not enable them to learn. (Nix, 2005, p.9)

Although the system provided tools for communication, such as phone calls and SMS, the study found that participants did not use any communication functionality for the module. This finding differs from some other mobile learning projects, such as the Mobile Learning Organiser (Corlett et al., 2005), where students made considerable use of the communications facilities of the PDA devices. Further research is needed into the preconditions for successful mobile communication in learning, such as having a shared task and opportunities for face to face meetings.

A general conclusion from the major European mobile learning projects is that while delivery of educational content to mobile devices may have specific uses in training and professional development, there are other approaches to mobile learning that can make better use of the distinctive properties of mobile technology, including context-based guidance, learning through conversation, and mobile media creation.

Pedagogical and theoretical perspectives on mobile learning

The foundational projects were also influential in shaping the development of pedagogical and theoretical perspectives on mobile learning. The first years of mobile learning saw a number of technology-driven projects that explored the utilisation of new mobile technology to support teaching and learning. However this techno-centred view was soon challenged within the field and more elaborate views of mobile learning were articulated along with the first attempts to theorise mobile learning. A brief account of this process and its outcomes is presented here.

Mobile learning pilots and projects have had diverse aims and pedagogical approaches. It could be said that there is little to connect delivery of location-based content on mobile phones with group learning through handheld computers in the classroom, apart from a reliance on handheld devices, so early definitions of mobile learning were anchored on the use of mobile technology:

> It's elearning through mobile computational devices: Palms, Windows CE machines, even your digital cell phone. (Quinn, 2000)

However, the focus on technology does not assist in understanding the nature of the learning and overlooks the wider context of learning. In many of the more recent projects, the mobile technology, while essential, is only one of the different types of technology and interaction employed. The learning experiences cross spatial, temporal and/or conceptual borders and involve interactions with fixed technologies as well as mobile devices. Weaving the interactions with mobile technology into the fabric of pedagogical interaction that develops around them becomes the focus of attention:

> …research attention should be directed at identifying those simple things that technology does extremely and uniquely well, and to understanding the social practices by which those new affordances become powerful educational interventions. (Roschelle, 2003, p.268)

Moving the focus away from the mobile technology and towards the social practice it enables, allows for a different conceptualization of mobile learning. Kakihara and Sørensen (2002) argue that mobility should not be linked exclusively to human movement across locations and examine three interrelated aspects of mobility: spatial, temporal and contextual. They propose that mobility arises from the interactions people perform, and that mobile devices enable "patterns of social interaction [that] are dynamically reshaped and renegotiated through our everyday activities significantly freed from spatial, temporal and contextual constraints" (p. 1760).

Traxler (2007) argues that mobile devices change the nature of knowledge and discourse, and consequently the nature of learning and learning delivery. They alter the nature of work and they enable new forms of art and performance, thus making mobile learning "part of a new mobile society" (Traxler, 2007:5). This new mobile character of society manifests itself, for example, in the mobile culture developed amongst young people and the increasingly fragmented and mobile work and leisure practices.

Viewing mobility as an emergent property of the interactions between people and technologies places mobile learning under a different light. While discovering a city during a vacation, a tourist may have learnt about it though multiple channels: from a travel internet site on a home desktop computer, a phone conversation to a friend who visited the city, an in-flight travel magazine and promotional video, a Google map of the city on a mobile phone, an interactive multimedia guide in the tourist information office, printed brochures, handheld audio-guides in the tourist locations, and interactions with local people. It is the combined experience that constitutes mobile learning.

We follow Kakihara and Sørensen (2002) in examining an extended notion of mobility, but employ 'context' as an overarching term to cover interrelated aspects of mobility:

- *Mobility in physical space*: people on the move trying to cram learning into the gaps of daily life or to use those gaps to reflect on what life has taught them. The location may be relevant to the learning, or merely a backdrop.
- *Mobility of technology*: portable tools and resources are available to be carried around, conveniently packed into a single lightweight device. It is also possible to transfer attention across devices, moving from a laptop to a mobile phone, to a notepad.
- *Mobility in conceptual space*: learning topics and themes compete for a person's shifting attention. It was already shown in the early 70s that a typical adult undertakes eight major learning projects a year (Tough, 1971), as well as numerous learning episodes every day, so attention moves from one conceptual topic to another driven by personal interest, curiosity or commitment.
- *Mobility in social space*: learners perform within various social groups, including encounters in the family, office, or classroom context.

- *Learning dispersed over time*: learning is a cumulative process involving connections and reinforcement among a variety of learning experiences (Dierking et al., 2003), across formal and informal learning contexts.

Research into mobile learning then becomes the study of how the mobility of learners, augmented by personal and public technology, can contribute to the process of gaining new knowledge, skills and experience. The challenge here is to define the role of pedagogy and theory in this process.

Depending on the social practices that develop around the use of the mobile technology, different (established) theories of learning become relevant. Naismith et al. (2005) review mobile learning projects and applications that fall under the auspices of behaviourist learning, constructivist learning, collaborative learning, situated learning and informal learning. Kukulska-Hulme and Traxler (2007) maintain that mobile technologies can support diverse teaching and learning styles, and lend themselves particularly well to personalised, situated, authentic and informal learning. The common denominator is context: physical, technological, conceptual, social and temporal contexts for learning. Traxler (2007) argues that a theory of mobile learning "may be problematic since mobile learning is inherently a 'noisy' phenomenon where context is everything" (p6).

Context, then, is a central construct of mobile learning. It is continually created by people in interaction with other people, with their surroundings and with everyday tools. Traditional classroom learning is founded on an illusion of stability of context, by setting up a fixed location with common resources, a single teacher, and an agreed curriculum which allows a semblance of common ground to be maintained from day to day. But if these are removed, a fundamental challenge is how to form islands of temporarily stable context to enable meaning making from the flow of everyday activity.

Sharples et al. (2007b; in press) propose a characterisation of mobile learning as the private and public processes of coming to know through exploration and conversation across multiple contexts, amongst people and interactive technologies. Their analysis draws on the conception of learning as a tool-mediated socio-cultural activity (Engeström, 1996) to examine how knowledge is constructed through activity in a society that is increasingly mobile. They argue that conversation and context are essential constructs for understanding how mobile learning can be integrated with conventional education, as mobile learning offers new ways to extend education outside the classroom, into the conversations and interactions of everyday life.

To conceive mobile learning as a continuous, almost all-encompassing, activity presents important issues regarding the ethics of mobile learning, in matters such as who owns the products of conversational learning (online discussions, Wikipedia pages, etc.) and what are peoples' rights to be free from continual engagement with educational technology. It also challenges views of formal education as the transmission or construction of knowledge within the constraints set by a curriculum, calling instead for the exploitation of technology in bridging the gap between formal and experiential learning.

Recent mobile learning projects

In this section we describe a wide range of recent European projects that exemplify this depiction of mobile learning, showing how learning can be supported across contexts and how mobile technologies can support new learning activities that go beyond traditional educational practices. The projects illustrate learning across different educational contexts (schools, universities, museums, informal learning, professional development and workplace settings), with diverse target groups (including children, adult learners, and professionals).

Mobile Learning in School

We first present three school projects ranging from a more mature initiative, Learning2Go, to the most recent experimentations, Nintendogs. They exemplify different models of technological approaches, including the adoption of existing familiar and popular devices and applications (in Nintendo DS and Nintendogs); the development and deployment of new architectures and applications (in ENLACE); and the personal ownership model of somewhat 'unfamiliar' devices integrated with familiar hardware and software.

Learning2Go (Faux et al., 2006) is a large scale school-based mobile learning initiative in Wolverhampton, UK. Currently in its third year, it involves 18 institutions, from nursery to secondary school including special needs schools, and over 1000 students. The project embeds and blends TEL (technology enhanced learning) into the educational practices of schools. It endorses collaborative approaches and promotes learners' responsibility in shaping their own learning. Student ownership and 24/7 access to a handheld device is central to the approach. The Fujitsu Siemens EDA (Educational Digital Assistant) running Windows Mobile 5 is presently in use and the integration of these with pre-existing software and hardware has enabled, for instance, scenarios encompassing networked interactive whiteboards and EDAs. The schools have different aims which include devising mobile learning practice, encouraging independence and motivation, gaining parental engagement, and raising standards, among others. Practices to be highlighted include: the 24/7 adoption with young children (age 5-6) which allows them to work at home together with their parent using specially designed PDA-based numeracy packs; primary school children moving on to secondary schools bringing their PDAs with them; and a secondary school math class where arithmetic exercises are performed on the networked PDAs in tandem with a SmartBoard from which pupils can copy the exercises directly and through which individual PDA screens can be shared.

The ***ENLACE*** (Verdejo et al., 2007) project explores the design and implementation of a technological infrastructure to support a workflow of collaborative learning activities, in and out of school. The infrastructure relies on a Learning Object Repository (LOR) which addresses the reusability of materials and provides interoperability mechanisms for various tools, such as a voting system and data representation applications. A nature trail is the framework for cross-curricular learning. In-class activities prior to the field trip include preparation using multimedia materials and the voting system, and generation of the field trip activities by selecting components from the LOR. The field trip activities can be generated by the teacher, the students, or both. Outdoors, the students complete the activities using PDAs and gather data. Back in the classroom, they upload their work to the LOR, analyse the data collected, and create representations of, for instance, a topographic profile of the visited site.

Nintendogs[3] (2008) is a games-based-learning project involving two Primary 2 classes (6-7 year old children) in Aberdeenshire, Scotland. The idea originated from the teachers and uses the Nintendogs game for Nintendo DS as the context for creating a cross-curricular learning hub. The game features a puppy that players have to care for in order to ensure it grows happy and healthy. Dogs can be trained and taken to dog shows where they can win prizes; subsequently, earnings can be spent in dog shops. Learning activities springing from the game involve writing stories and posts for student blogs, role playing a Vet's surgery in class, maths related to prizes won and purchases made, and even the establishment of a real dog walking service. Students are encouraged to take pride and ownership of their project and the learning activities, and are engaged in peer-tutoring involving older classes and their own classmates.

Mobile Learning in University Settings

University and college mobile learning projects are currently less mature and more experimental than those in schools, though wireless support for students with laptop computers is becoming widespread. They have focused on supporting students' active

engagement and participation while on and off campus. However, unlike in the school context, tertiary education projects do not seem to be overly concerned with connecting the lecture theatre with the outside world and bringing students out into it. The approach is more focused on supporting students' learning wherever they are rather than displacing them somewhere to learn. This may be due to the less directive nature of third level education.

StudyLink (Naismith, 2007), ***TVremote*** (Bär et al., 2005), and ***Pls Turn UR Mobile On*** (Markett et al., 2006) are three SMS university-based initiatives intended to portray the volume and diversity of projects in this area. StudyLink investigates the feasibility of an 'email to text message' service for administrative communication between university staff and students. The latter two respectively explore the in-class use of SMS to deliver students' feedback to lecturers, and to promote student-initiated interactivity loops. All make use of students' own mobile phones and existing mobile networks and services but have developed purpose-built applications to manage and display the SMS correspondence. Costs incurred during the projects have been absorbed internally by the projects, but cost is generally highlighted as a barrier for the wide adoption of SMS learning activities.

Other projects have targeted students on practice-based courses that include clinical placements. For example, the ***myPad*** project (Whittlestone et al., 2008) addresses the issue of supporting university students' active engagement in learning while off-campus. In particular, it aims to support veterinary students in clinical practice and it offers a web-based clinical activity tool accessible through handheld devices. The capabilities of the devices (HTC M3100 and HTC M5000) and functionalities of the tool allow learners to write notes and reflections on cases, to capture graphical or audio data, and to attach these and any other relevant resources to the notes.

Mobile Learning in Museums and Informal Learning Settings

We present here five projects that describe how different technologies and design approaches have been used to support learning in museums. These are settings that can facilitate informal learning, although in many cases the learning experience is given an overall structure by a teacher. The majority of these projects have introduced mobile phones as a central device for data collection, communication and content delivery.

In the ***Mystery at the museum*** (Cabrera et al., 2005), groups of students are engaged in collaborative game-based problem solving to augment their interaction with the museum. Before the visit, the teacher provides general background information. At the museum, groups of students receive additional information through mobile devices, related to the exhibits and the problem-solving ('mystery') task. Each group is assigned a different part of the task that they have to carry out collaboratively. More specifically, each group is assigned a set of puzzles, and each group member receives a random collection of pieces from the group's puzzles. Group members then have to exchange puzzle pieces as necessary for each group member to solve their own puzzle. Putting all the group puzzles together helps the group to complete their task.

The ***MyArtSpace*** project enables children visiting a museum with their school to work in groups and carry out inquiries related to the museum content (for more details see Sharples et al. 2007a; Vavoula et al. 2007). Before the visit, the teacher sets the class a big question to explore in the museum, and works with them to develop related skills of evidence assessment and collection. At the museum, the children are loaned mobile phones and work in groups to explore the museum and collect exhibits and personal audio, photo and text notes, all related to their inquiry task. Back in the classroom, the children use the collected items to create, present and share personal galleries that demonstrate the outcomes of their inquiry activity. This has now been developed as a commercial service[4].

The aim of the ***Gidder*** project is to support and extend collective knowledge building across classroom and museum settings. In advance of the museum visit, the students

work in groups in the classroom to select artworks in the Gidder wiki that interest them, select those they will be focusing on in the museum, and write related labels (Pierroux, 2008). Each group has its own workspace. At the museum, students explore the exhibition and their selected artworks and use their mobile phones to send multimedia messages (MMS) with labelled information to the wiki's blog. These are shared with the rest of the class. Back at school the groups use the wiki and blog resources to discuss and develop their group interpretations. The wiki labels from all groups appear in a tag cloud, which helps to foster awareness of the interpretation process across groups as well as to scaffold interpretation.

Bletchley Park is a historic site of secret British codebreaking activities during World War II and birthplace of the modern computer. While touring the site, visitors can use their mobile phones to send text messages (SMS) containing specific text terms to a dedicated mobile phone number about exhibits that interest them. The text terms are displayed on special **Bletchley Park Text** signs next to the exhibits (Mulholland et al., 2005). Back home, visitors then have access to additional content related to their selected exhibits. Access to the web site is authorised by their mobile phone number. After login they can semantically browse their selected content and add further text terms as needed.

Following up personal interests and sharing them with others, are strong features of all these projects. A further way to promote this is to connect 'virtual' visitors with those who are physically present in a museum. Developed as part of the Equator project, the **City** system allows three visitors, one on-site and two remote, to visit the Charles Rennie Mackintosh room in the Lighthouse Centre for Architecture, Design and the City, in Glasgow, simultaneously (Galani & Chalmers, 2003). The on-site visitor carries a PDA that is location-aware and displays the changing positions of all three visitors on a map of the gallery. The two off-site visitors use two different environments: a web-only environment and a Virtual Environment (VE). The web visitor has access to a map of the gallery, and the VE visitor uses a 3D display of the site with avatars representing the location of the other visitors. All three visitors share an open audio channel, enabling them to converse in real time. The off-site visitors have access to multimedia information that is presented to them as they move around the map. All visitors can look at the same display when in the same location.

Mobile Learning for Professional Development and Workplace Settings

Mobile technologies have not only been used to support learning in schools, universities and museums but also in professional development and workplace settings. The projects below present a number of different cases that combine various educational approaches and technologies in the field of medical education and in-situ competence development.

The aim of the ***Knowmobile*** project (Smørdal & Gregory, 2003) was to explore how wireless and mobile technologies, in particular Personal Digital Assistants (PDAs) could be useful in medical education and clinical practice. This project brought together academic and industrial partners aiming to support Problem-Based Learning (PBL) and Evidence-Based Medicine (EBM) following the medical education reform in Norway. Some of the research questions under investigation were as follows: What does 'just-in-time' access to information mean in clinical settings? How can health professionals be helped with access to the most up-to-date medical information? The medical students that took part in these trials were given different mobile devices (PDAs and PDAs with GSM capability) and were placed in distinct educational settings. The results of the trials reveal that students were using the devices mainly to access information from the digital medical handbook (available as an e-book in each device) and as communication devices (mainly sending SMS messages and to coordinate social activities). The results of this project show that the use of PDAs in medical education should be tightly embedded in social and technical networks in which the activity is taking place. The authors summarized that PDAs should not only be considered as Personal Digital

Assistants, but rather as gateways in complicated webs of interdependent technical and social networks.

In the ***MeduMobile*** project (Schrader et al., 2006) mobile video communication and notebooks were used to develop learning scenarios to support medical students and teachers in the field of pathology. These scenarios were tested and evaluated by medical students in Germany. The main educational goal was to train students in various medical routines, conferences or meetings such as doctor-patient bedside conversation. These activities were filmed by video teams and broadcast live via the WLAN of the Charité campus to medical students attending different courses. One type of learning arrangement was the autopsy conference as an on-call scenario. The MeduMobile seminar system was used to broadcast the video sessions to thirteen access points available on two campuses. A questionnaire was developed to investigate the response and attitudes towards the use of the mobile seminar system. The responses from the participants indicate a high acceptance rate of using this type of mobile learning to support difficult medical cases that can promote complex learning.

In the Danish ***Flex-Learn*** project (Gjedde, 2008), the Danish University of Education together with industrial partners are investigating new ways to support truck drivers' competence development using mobile video-based learning. This project uses 3G enabled mobile phones and PCs as a learning platform. Mobile video materials have been developed to support experiential and situated learning in realistic work situations. Learning activities include video learning with a mobile video coach, certification and remediation of content. The digital materials developed for these different purposes support multimodal learning experiences including videos, sounds, textual overlays and multiple-choice questions. The project uses a learning management system that gives an overview of the various mobile and PC activities at all times. An action research approach has been used in the design phases of the project. Data collection methods include observations and interviews during three pilot courses, as well as testing the use of the system on the road with four truck drivers. Preliminary results of these trials indicate that truck drivers have positive attitudes towards this type of learning, especially when it can be integrated into the workplace. The Ministry of Science has funded Flex-Learn and the project is now entering a commercialization phase.

Derycke and colleagues (2007) at the University of Lille in France are exploring the potential of using pervasive computing and devices to provide dynamic adaptation of information contents and services according to various contexts. They have developed a system called ***Personal Training Assistant*** (PTA), that combines mobile devices and SmartSpaces (sensors such as RFID tags and Bluetooth devices) to support workplace learning in shops and supermarkets, in the particular domain of Hifi/Video equipments. The central idea is to utilize the mobile device, provided to the seller for several additional purposes (stocks management for example), in order to support both learning and coaching of the seller/learner in a variety of contexts. This particular project illustrates an emerging line of research in the field of mobile learning, of enriching the interaction between concrete objects and people supported by the use of sensors and contextual computing. At this stage, the project is in its implementation phase.

Discussion of the projects

It is interesting to note that, in all the above projects, fixed technologies like desktop PCs play an important role in the boundary crossing between different learning contexts. Without downplaying the role of mobile devices and technologies in situating learning within authentic contexts, none of the projects is limited to a mobile device to implement the whole of the learning experience. Although the mobile device may enable initial in-context interaction and content delivery that can stimulate interest, its most innovative use is in book-marking areas of interest and creating context annotations that can trigger and support follow-up learning. This follow-up learning is in most cases supported by fixed technologies. Many of the projects discussed above involve elements of inquiry-based and problem-based learning. This is not surprising in

relation to museums and similar settings, as they have been identified as ideal environments for inquiry-led learning (McLeod & Kilpatrick, 2001).

Mobile technologies offer the potential for a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different learning contexts. Chan et al. (2006) use the term "seamless learning" to describe these new situations. Seamless learning implies that students can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using their personal mobile device as a mediator. These scenarios include learning individually, with another student, a small group, or a large online community, with possible involvement of teachers, relatives, experts and members of other supportive communities, face-to-face or in different modes of interaction and at a distance in places such as classrooms, outdoors, parks and museums. In describing projects in this paper, we have illustrated examples of seamless learning spaces that augment physical spaces with information exchanges as well as geospatial mappings between the mobile device and the real-world to facilitate navigation and context-aware applications. According to Pea and Maldonado (2006) these features play an important role in designing mobile applications with an emphasis on inquiry processes, social constructivist theories, and distributed cognition designs.

We have shown how mobile technologies have been used in Europe to support learning across various contexts with diverse target groups, and according to different learning principles underpinning design, development and implementation. The projects demonstrate how a combination of mobile and fixed technologies can sometimes support different parts of the learning experience. More importantly, they demonstrate how this blend of technologies and educational approaches can support the design of learning experiences that cross spatial, temporal and conceptual boundaries, and interweave with the learner's everyday life and into her web of personal knowledge, interests and learning needs. In the sections which follow we consider how mobile learning is having an impact on broader educational practices.

Teacher development

Although almost all schools across Europe currently forbid the use of mobile phones in the classroom, it is becoming clear that children are engaging in subversive phone use. As part of a recent study for Becta of children's use of technology undertaken by the University of Nottingham, 2611 children in Years 8 and 11 from 27 schools were surveyed. A series of questions asked about their mobile phone activity. 33% of children reported having sent a text message at school for work purposes, 24% reported taking a photo and sending it by phone at school (for work) and 36% reported accessing the internet by phone at school (for work). This is despite mobile phones being banned in class at the schools surveyed.

It is important to consider the perspective of teachers (at all education levels) and the opportunities they have for professional development in this area of technology use. At European and individual state level, there appears to be little teacher development or training activity addressing mobile learning. However the issues of training and other forms of development have been explored through a number of projects, revealing contrasting perspectives on adoption of mobile technologies into formal education.

An obvious factor influencing teacher perception and adoption of mobile technology as a tool for learning, is ready accessibility of devices (Mifsud & Smørdal, 2006). Yet researchers investigating the provision of handheld devices to support trainee teachers on placement in schools (Wishart, 2008; in press; Wishart et al., 2005) have reported low levels of usage despite a year-long loan arrangement. Trainee teachers reported unease with the use of handheld technologies in the presence of other teachers or even in class (ibid). In a similar vein, veterinary students in clinical practice taking part in the myPad project (described earlier), reported infrequent handheld usage (Whittlestone, 2008). They, too, felt it was inappropriate to use their handheld in the surgery and in

front of clients and were fearful that observers could have thought they were texting or playing games (ibid).

These two examples of trainees' refusal to use their handhelds when in professional settings raises interesting issues in relation to social codes of acceptable use of mobile technologies. Wishart (in press) argues that trainee teachers on placement in schools have not yet formed their pedagogical identities and hence are particularly vulnerable to existing school cultural norms and pedagogical practices in the school. However, some teachers are making efforts to change existing practices. The AMULETS project, (Spikol, et al., 2008) explores how teachers can develop and implement novel educational scenarios combining outdoors and indoors activities that use mobile computing technologies together with fixed computers. Järvelä et al. (2007) have also tried to show teachers how collaborative learning can be structured and regulated with wireless networks and mobile tools in higher education.

Lessons learnt from successful projects such as the Multimedia Portables for Teachers Pilot (MPTP) (Harrison et al., 1998) indicate that some teachers can also engage successfully with technology when there is no formal training structure and they are given freedom to decide when and how to use it (Fisher et al., 2006). This enables the emergence of meaningful and contextualised learning about and with the technology (ibid).

A recent review on Teachers' Learning with Digital Technologies (Fisher et al., 2006) highlights that, contrary to common assumptions, teachers' learning does not have to be implicit. Like their students, they too can benefit from playful, active, and experiential learning in which the opportunity to construct, enact, and revise their learning path is granted. A performance-driven culture, endorsed by many educational establishments and enforced through curricula and assessment, also affects teachers and their organisation of teaching and learning. Although teachers' knowledge encompasses knowing their subject and strategies to teach, it is recognised that in this rapidly changing world they will need to learn to teach in ways they have never been taught (ibid). In particular when learning about technology, teachers should be given opportunities to engage in purposeful activities (ibid) in which the affordances of technologies are made explicit so that they can make informed decisions (Conole & Dyke, 2004).

Education Policy for Mobile Learning

We now discuss the extent to which e-learning policy and initiatives are being shaped by research project results and the potential of mobile learning. The European Commission has been influential in promoting mobile learning through the Framework programmes, leading to a growing awareness by policy makers of opportunities for extending formal education by adoption of mobile technology.

In the UK (chosen here as an exemplar), policy makers have shown awareness of developments in mobile learning by commissioning research overviews and signalling the emergence of mobile technologies among the many new tools available to learners. In 2004-5, JISC, the Joint Information Systems Committee, commissioned a series of case studies and a landscape study of mobile learning practice across the post-16 sector (Kukulska-Hulme et al., 2005b; Kukulska-Hulme et al., 2005a). Becta, the UK agency for learning and technology, has commissioned a series of reports on mobile learning, the most recent being from the University of Bristol (McFarlane et al., 2008). The report indicates that the main policy issues to be addressed are those of sustainability and scaleability, with a need for new models of funding and support if examples from successful pilot projects are to be more widely adopted. While the importance of mobile learning has been acknowledged by senior policy makers in the UK, it has not yet been translated into strategy. Thus, the UK Government is developing policy to connect home and school access to learning (DCSF, 2008, p. 77), but does not explicitly mention the value of mobile technologies. The main UK strategy document

for technology across all education sectors makes only one passing reference to mobile devices (Becta, 2008a).

At the same time as policy in formal education is being challenged by emerging practices, there is some evidence that ideas about the value of informal learning, and the role of mobile technology in support of this, are beginning to shape educational policies and strategies. A recent technology strategy for further education, skills and regeneration in England (Becta, 2008b) acknowledges developments such as the increase in personal handheld devices, but notes that although helpful, these also "bring new challenges to the system" (p.22). The Department for Innovation, Universities and Skills in England has issued a consultation document (DIUS, 2008) which highlights the role of handheld devices; it is intended that this consultation will mark the start of a debate that will lead to a policy paper on informal adult learning for the 21st century:

> Ever-expanding learning opportunities are possible through the availability of hand-held devices, wide access to broadband and wireless connections… Chip technologies will increasingly enable information in galleries, museums and architecturally interesting buildings to be available through mobile phones, which will in turn provide routes to post-visit discussion groups, further educational material, and/or informal and formal learning… (DIUS, 2008, p.26-28)

A research project report for the Higher Education Academy on bridging formal and informal learning (Trinder et al., 2008) also recommends that more emphasis should be placed on mobile devices and universal free access to high-speed networks from anywhere within the campus. However the process of implementing such recommendations is not always a smooth operation.

There seems to be consensus in our field that the inherent characteristics of mobile technologies are particularly well suited to support learning rooted in social, constructivist, contextual and collaborative principles. They offer the opportunity for rich, authentic learning in which curriculum, timetable, and assessment do not constrain learners' playful experiences, crossing boundaries between formal and informal learning.

Conclusions and future challenges

This paper has presented a reflective overview of developments in mobile learning from the perspective of researchers working in Europe. Context has been identified as a central construct in mobile learning developments, guiding projects to use mobile technologies to help connect learning across contexts and life transitions, and to form bridges between formal and informal learning. Learners' personal interests are frequently supported through mobile technologies; learner collaboration is also important, and specifically the ability to support collaborative and conversational learning taking place outside the classroom, in homes, workplaces and in museums. User interface and interaction design has addressed some of the requirements of mobile learners in these contexts, although there is still much to be done. The European perspective is also characterised by an interest in rethinking pedagogical approaches, seeking to widen learner participation, and in developing theoretical perspectives on mobile learning.

The Commission of the European Communities (2008) is currently preparing Europe's 'digital future' through the identification of strategic challenges for competitiveness and ICT take-up in Europe. It is anticipated that the implementation of Internet Protocol IPv6 will "allow more novel applications based on wireless technologies, which will expand broadband connectivity to include new mobile devices enabling ubiquitous usage"; in particular, RFID and sensor technologies embedded in products will extend the Internet to the 'Internet of Things' (ibid, p.5). European researchers in mobile and ubiquitous learning will be keen to tackle the new challenges arising from learner

activity across multiple virtual and physical contexts, spanning formal and informal learning. This will require a combination of technical, pedagogical and sociological expertise to be able to make sense of, and give some direction to, emerging forms of mobile and blended learning.

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