

Mobile Learning: Research, Practice and Challenges

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Abstract:

Over the past ten years mobile learning has grown from small-scale studies to large national and international projects, but it still lacks an evidence base of comparative studies and research into large-scale deployment. Existing systems can be described along a dimension of 'formality', ranging from mobile devices in fixed settings such as classrooms managed by a teacher, to highly mobile learning applications in informal learning, controlled by the learner. Recent research has investigated the concept of 'seamless learning' with the aim of supporting a continuity of learning across contexts and devices, for example to connect learning in classrooms and on school museum visits. Factors influencing the success of mobile learning include: availability of technology, institutional support, connectivity, integration into everyday life, and ownership by the learners. Some challenges for the future include improving the usability of mobile learning technology, designing new forms of informal learning supported by personal mobile devices, and evaluating learning that occurs outdoors and across locations.

Keywords: mobile technology, informal learning, evaluation, one-to-one classrooms, personalisation, ownership

Research and practice in mobile learning are still in their infancy. Over the past ten years the field has moved from small-scale research studies to some large national and international initiatives, such as the EC-funded MOBIlearn and m-Learning projects, a growing number of commercial services, and many institution-based projects. The evidence from research is mostly in the form of case studies that report the progress of a project, with accounts of their successes and difficulties drawn from observations by the researchers and interviews with participants. There have been a few attempts to carry out small-scale comparative evaluations of specific technologies, such as mind mapping tools on handheld computers, and a very small number of studies that have compared learning outcomes of classroom trials of handheld technology to traditional teaching. This paucity of quantitative and comparative data is entirely understandable given the rapid pace of developments in the technology and the time and resources needed to carry out a useful comparative evaluation. What is the value of running detailed educational evaluations of a prototype mobile learning system implemented on last-year's handheld technology?

Thus, a critical reader of this paper may find that the evidence of what research has to say for practice is, at best, unreliable and outdated. However, taking a broader perspective, we find a fairly consistent pattern of reports about what works and what doesn't. We shall take an illuminative approach – attempting to shine a light on the emerging technologies and activities in mobile learning that appear, from a variety of evidence, to be supporting good practice in teaching and learning. We shall also

attempt to focus on issues and problems, from technical failures to unexpected problems of engaging learners or supporting effective teaching.

To start, we need to clarify what is meant by ‘mobile learning’. The concept, like the technology, has developed over recent years, from the use of handheld devices in classrooms, through the use of technology to support learning in context and on the move, towards a broader investigation of learning in a mobile society. One definition that captures the dual perspectives of learner mobility and learning with portable technology is the following: *Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies* (O’Malley et al. 2003)

To provide a structure for the paper, we shall begin with the two most active and promising areas of research, which are the use of portable technology to support curriculum learning in the classroom, and the use of personal mobile technologies for learning on the move. These can be seen as two ends of a dimension from enhancing classroom learning through devices such as handheld response systems, to learning as part of everyday life by informal communication and knowledge sharing with mobile phones (Figure 1).

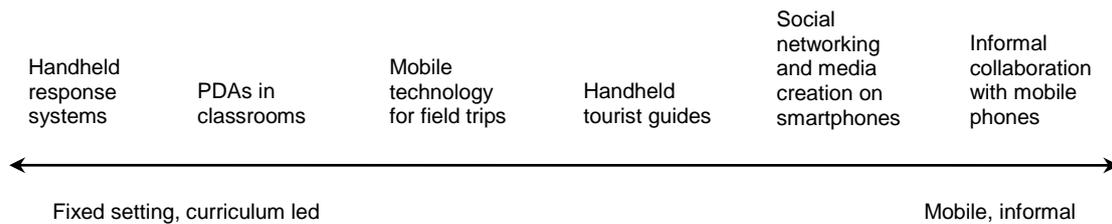


Figure 1. Some types of mobile learning across the dimension from curriculum-led classroom to informal highly mobile.

Some more recent projects, such as MyArtSpace (Vavoula et al., 2009), have employed mobile technology to make connections between learning in the classroom and outside, which can be seen as technology enabling the expansion of curriculum-led learning to new contexts. At the other end of the dimension, pupils and university students are bringing their personal mobile technology such as phones and media players into classrooms and lecture theatres, resulting in new opportunities and challenges for formal education. In this paper we shall start at each end of the spectrum, suggesting how research can inform practice in curriculum-led and personal learning, and then suggest some implications from the research into mobile learning across contexts. We also address the special requirements of distance and online education, which is typically curriculum-led but responds to the needs of learners who may be highly mobile and need to combine work and learning.

Handhelds in the Classroom

Response systems to augment classroom learning

Roschelle surveys reports on the use of classroom or lecture room response systems (Roschelle, 2003). In its simplest form, a teacher poses a short multiple-choice question. Each student selects an answer on a handheld device like a TV remote control. The system instantly collects and aggregates all students' responses and presents them in a coherent form, usually a histogram. Although the form of response is limited, adopters have indicated how the devices can support formative assessment, allowing the teachers to assess the learning of individual students and also to track the general level of understanding as a class progresses (Davis, 2003; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996; Owens, Demana, & Abrahamson, 2002).

Importantly, students can see where fellow students share their misunderstandings, and that they are not alone. Further, because the displayed responses are anonymous, embarrassment is reduced (Owens et al., 2002). Teachers can check for understanding with conceptual questions (with common misconceptions as possible answers) and are frequently surprised by the results (Dufresne et al., 1996). (Roschelle, 2003)

Using graphical devices such as graphing calculators or handheld computers as input devices allows the students to respond in more flexible ways. For example, one application overlays all the data from the students' screens (such as graphs drawn by the students in answer to a question) onto a single classroom display seen, to show the variety of student responses (Roschelle, 2003).

Questions by SMS

At the University of Cape Town, Ng'ambi (2005) used SMS provide individualised responses to students in large classes. Students can submit an anonymous question (dynamic frequently asked question or DFAQ) by SMS. This is added to a website where peers can see the question and, where possible, respond to it. After a delay an email notification is sent to the tutor. The response is sent back via SMS, but is also available on the website as a resource for the whole class to view. The students can thus learn from exposure to other students' questions and the tutor receives important feedback on where students' difficulties lie. A similar system to support students sending SMS in real-time, in class, via their personal mobile phones, was developed by Markett et al. (2006). The lecturer could view messages and respond during class; the messages were also available online after class, allowing conversations to further develop via threaded comments. Initial evaluations showed an increased willingness among students to ask questions in class.

Small group learning with wireless handheld computers

A team of researchers in Chile have developed a mobile computer supported collaborative learning (MCSCCL) model (Zurita & Nussbaum, 2004) to address problems with coordination, communication, management and lack of mobility that are inherent in traditional collaborative learning activities. Students work in small groups around a table, with each student operating a handheld computer. The devices are networked by wireless so that the learning interactions can be automatically managed and coordinated. Typically, the students are set a series of problems shown on the handheld devices. The student has to solve the problem alone, then when each person in the group has proposed an answer, their computers show all the results for the group. If they differ, then the members of the group have to discuss and resolve their differences to produce an agreed answer. This is then sent by the device to the teacher, who is able to monitor both the progress of individual students and the

groups. Valdivia and Nussbaum (2007) have carried out a comparative evaluation of forty students over a sixteen-week semester on a computer science course studying with MCSCL compared to traditional teaching methods. The study showed significantly higher achievement for the experimental group students on midterm and final exams.

Motivation in the classroom and on campus

Some projects have indicated that the use of mobile technology increases the motivation of learners. For example, Swan et al. (Swan, van't Hooft, Kratcoski, & Unger, 2005) indicate that when mobile computing devices were introduced into classrooms in Ohio, USA, students and teachers alike observed an increase in motivation, leading to increases in both the quantity and quality of student work. In some instances, greater motivation may be attributed to using mobile devices in conjunction with certain types of activity, for example games. There is growing evidence that mobile devices can facilitate 'immersion' in location-based activities that also feature some elements of game-playing. Schwabe & Göth (2005) developed an orientation game in a university setting and concluded that there is something about gaming that "deeply touches people of all ages and can lead through immersion to fun" (p.215). It should be noted that researchers often reflect on the possible 'novelty effect' of using a mobile device for learning, which could wear off after a while. Currently there is a lack of longitudinal studies establishing longer term impacts on motivation.

Participatory simulations

An innovative use of handheld computers has been to allow students to participate in a simulation, for example to explore the spread of a virus by passing it from one handheld computer to another through infrared 'beaming' (Colella, 2000). One or more students start with a device that is 'infected' by an imaginary virus. As the students move around and 'beam' messages to their fellow students, the infection spreads. One by one, after a preset incubation time, the devices become 'ill'. The students can see data and graphs of the spread of the virus over time and can try to deduce where the virus began. For example, they can attempt strategies such as to quarantine infected devices or slow their rate of social interaction. They can replay the game, changing parameters such as the number of initial infections and the incubation time to see how that affects the spread of disease. The researchers claim that students are engaged by taking part in a playful simulation rather than just observing it on a desktop computer and can 'get a feel' for a complex system by acting as an element in the simulation.

Personal and informal mobile learning

Self-directed language learning

In disciplines such as language learning, mobile device users have plenty of occasions to supplement formal learning with activities that support their personal needs. Song & Fox (2008) have tracked Chinese learners of English to see how they were using a mobile device to support and extend their learning in self-directed ways, in particular to build their knowledge of English vocabulary on a continuous basis. The study shows how the mobile device has helped learners to communicate informally and spontaneously about word meanings with other students and with lecturers, outside the classroom. These were motivated, advanced learners, who were willing actively to

define their own language needs and to select resources, tools and communication methods that would help them.

Going with the grain of everyday practices

Learning is increasingly intertwined with other everyday activities such as using a search engine to look up information or taking photos and sharing them instantly with others. To see how far mobile devices were embedded in the personal and professional lives of alumni from a Masters programme, and to find out about patterns of use, Pettit and Kukulska-Hulme (2007) asked about their everyday practices with mobile technologies. One aim was to see whether the alumni were undertaking new forms of 'learning', however personally and informally that might be interpreted. It was found that they engaged in practices such as downloading podcasts to read on the train, reading e-books, making video clips, browsing websites. Interviews showed how they wove particular devices and practices into their daily lives, especially when travelling. The fit appeared to be 'intense but provisional', and dependent on factors often outside the control of the individual, such as changes to the design of buses or train seats. Given the importance of actual use patterns, educators may wonder whether they should stay within those patterns, or whether they can ask learners to adopt a new device or a new usage of a familiar device. Pettit and Kukulska-Hulme suggest that the most effective approaches are likely to be 'open to both perspectives': uncovering existing patterns of use and working within them, but also seeking to enlarge the scope of use of mobile devices.

Learning and leisure

As more mobile devices come on the market with embedded GPS (global positioning system) functionality, the potential for its use in learning is growing. Clough et al. (in press) have researched a community of 'geocachers' and suggest that this leisure activity may offer useful models for ways in which the potential could be developed. Geocaching enthusiasts use a GPS device, or GPS on their mobile phone, to locate a hidden 'cache', typically concealed somewhere in the landscape, and what is more, they maintain surprisingly dynamic, informal online communities where information is shared and social contacts are made (e.g. Geocaching.com). The treasure hunt approach is enriched by other activities such as puzzles and events, and it is thought that these types of activity could help students with location-related learning in subjects like geography, history, or archaeology.

Handheld guides are now commonplace in museums and galleries and they are being extended to provide multimedia content and context-based services. An evaluation of the Caerus guide for visitors to a botanic garden found high satisfaction with the location-based content provided (Naismith et al., 2005). The audio commentary was particularly effective in offering an unobtrusive means to engage visitors with their physical surroundings, offer supplementary information, and narrate stories about the exhibits.

Handhelds in distance and online education

Learners who choose to take advantage of distance and online education can often benefit from the flexibility offered by mobile technologies. This could be flexible access to learning resources during periods of commuting and travel, at work, or even within the home. Another key role for mobile technologies is keeping distance and

online learners motivated, engaged and connected with other learners and tutors during what might be long term, interrupted periods of study. A particular advantage of a globally dispersed population of students is that they can use their handheld devices to capture data or contribute to the creation of learning resources in remote locations and make these resources available to others.

At NKI (Norwegian Knowledge Institute), Rekkedal & Dye (2007) have built up experience of developing and testing pedagogical and system solutions to support mobile distance learners. They report that learning materials have been developed for downloading to PDAs for off-line study, while interactions (such as access to forum discussions, responding to messages, communication with fellow students and tutors, and submitting assignments) were handled online via mobile devices when students were on the move. NKI have also developed and tested solutions for an 'always online multi-media environment' for distance learners based on the use of PDAs with access to wireless networks. Ideas for use of SMS and MMS services include reminders, notifications, quizzes, blogging, and communication among students and tutors. Rekkedal & Dye have been keen to ensure that both mobile and non-mobile distance learners are enabled to participate in the same course, using the same course materials accessible from standard and mobile technologies. There may not be an 'ideal' device and solution for mobile learning, they conclude, but what is most important is to take account of students' individual preferences.

Learning across contexts

Assisting curriculum learning outside the school or university

In the Learning2Go project (Faux et al., 2006), a large scale school-based mobile learning initiative in Wolverhampton, UK, schools have been trialling 24/7 adoption with young children (age 5-6) which allows them to work at home together with their parents, using specially designed PDA-based numeracy packs; and with primary school children moving on to secondary schools, bringing their PDAs with them to provide continuity.

The MyArtSpace project (Sharples et al., 2007) addressed the need to support children on school trips to museums and galleries by providing mobile phones running an application that provides multimedia content linked to exhibits and also automatically sends photos, audio recordings and notes captured at the museum to a website that provides children with personal records of their interpretations of the visit, which they can develop and share back in the classroom. An evaluation of the service indicated that it is effective in connecting learning in the classroom and museum and in enabling children to capture evidence to support inquiry learning.

Supporting learning on visits and field trips

The MANOLO project (2006) has demonstrated the advantages of using PDAs for university-level fieldwork in subjects like archaeology and environmental sciences, especially when using GPS (global positioning) to track people's movements within a nature reserve. Advantages include better use of limited time, greater accuracy of data recording, and improved communication. Through its case studies and 'lessons learnt', the project deliverables offer a great deal of practical advice to educators who are thinking about using mobile devices for field trips.

Learning between formal and informal settings

Mobile devices are increasingly presented as tools that support transitions between episodes of learning in formal and informal settings, or simply as a means of supporting and connecting a student's learning whether it be formal or informal. The Student Learning Organiser project (Sharples et al., 2005) showed that university students valued access to course materials and communications at home and on the move, but did not want a dedicated 'learning organiser' that was separate to widely-used office and communication tools. A small case-based research study on university students' use of mobile phones for learning, carried out by Cook et al. (2008), suggests that timely learning hints from the tutor (e.g. the whereabouts of resources relevant to an assignment) could play an important role in supporting mobile learners. On another level, their research highlights the need to understand affective issues surrounding learners' relationships to their mobile phones, and to challenge learners' preconceived ideas about what constitutes valuable learning.

Mixed reality learning

Mobile Mixed Reality is typified by games that are played in a physical environment augmented with virtual artefacts. Users may wear or carry mobile computers equipped with positioning technology and they interact with experiments and challenges designed to enhance their knowledge of the environment. The Ambient Wood project (Price & Rogers, 2004) enhanced a woodland with experiments for children to explore the effect of light and moisture on habitats. The project showed how a combination of physical and digital interactions in a rich and appropriate setting can support active exploration, initiation and reflection.

Seamless learning

Kuh (1996) proposed that what were previously distinct experiences of learning (in-class and out-of-class; academic and non-academic; curricular and co-curricular; on-campus and off-campus) should be bound together so as to appear continuous. Building on this notion of 'seamless learning', a global research collaboration proposed a manifesto for research into learning for a world where every person has a networked personal computing device and can use it to learn across a variety of contexts (Chan et al., 2006). Seamless learning implies that students can learn whenever they are curious, using personal devices and embedded learning technology to store, share and recall contextualised knowledge, creating an experience of continuity and the ability to switch rapidly from one learning project to another. Wong and Looi (2011) offer a survey of research into mobile seamless learning, identifying ten salient features which emphasise technology (access and multiple device types), pedagogy (multiple learning tasks and models) and the learner (spanning formal/informal, personalised/social, physical/digital learning across time and space).

Critical success factors

On the basis of a review of papers from the international mLearn conference series from 2002-5, Naismith & Corlett (2006) identified five critical success factors which they describe as follows:

- *Availability of Technology*: Whether provided *for*, or *by* the learner, successful mobile learning projects make mobile technology available.

- *Institutional Support*: Extensive and well thought out support resources, including staff training and equipment/software maintenance are essential.
- *Connectivity*: Successful mobile learning projects incorporate wireless network access, whether through local wireless LAN or over the mobile telephone networks.
- *Integration*: Successful mobile learning projects do not stand apart, but are integrated with the curriculum, the student experience or ‘real life’, or indeed any combination of the three.
- *Ownership*: Ownership of technology helps to promote ownership over learning. It is important that learners either own the technology or at least treat it as if they own it. This means the ability to use it any time they wish, to be free to customise or upgrade it, or even to use it subversively.

Issues and Implications

Improving Usability

The successful development of mobile learning is dependent on human factors in the use of mobile and wireless technologies. The majority of mobile learning activity continues to take place on devices that were not designed with educational ends in mind and usability issues are often reported. Usability findings from empirical studies have been drawn together by Kukulska-Hulme (2007); key aspects that need to be considered are the physical attributes of devices, content and software applications, network speed and reliability, and the physical environment of use. The interplay of social and physical mobile interactions can add layers of complexity. It is also emphasised that user experience needs to be tracked for longer than is customary, from initial use through to a state of relative experience with mobile technology.

Rethinking Mobile Learning Design

Characterisations of mobile learning found in the literature include words such as: ‘personal’, ‘spontaneous’, ‘opportunistic’, ‘informal’, ‘pervasive’, ‘situated’, ‘private’, ‘context-aware’, ‘bite-sized’ and ‘portable’. This implies a conceptualisation of mobile learning in terms of the learners’ experiences with an emphasis on device ownership, informality, movement and context that will always be inaccessible to conventional e-learning (Kukulska-Hulme and Traxler, 2007). Designing for mobile learning begins by considering how deployment or use of mobile technologies will support this conceptualization, or consideration of how any proposed learning activity relates to the above attributes.

Developing new methods of evaluation

Mobile learning supports education across contexts and life transitions, which poses substantial problems for evaluation. Sharples (2009) has noted that there may be no fixed point to locate an observer, the learning may spread across locations and times, there may be no prescribed curriculum, the learning activity may involve a variety of personal, institutional and public technologies, it may be interleaved with other activities, and there may be ethical issues concerned with monitoring activity outside the classroom. Successful evaluation and analysis methods have included diaries and interviews, multi-level analysis for school museum visits and critical incident analysis to reveal breakthroughs and breakdowns in the use of mobile technology for inquiry science learning. In a summary of researchers’ reflections on current mobile learning research methods, Kukulska-Hulme (2009) proposes four key principles for future

research: it should be in tune with new thinking about learning; it should consider the impact of context; it should consider different types of data and analysis; and it should involve learners as co-designers or co-researchers.

Conclusions

Evidence from research in mobile learning should be treated with caution. This is a new and rapidly-growing area of research. Most studies of the effectiveness of learning on the move and in classrooms with mobile technology have been undertaken in the past five years, generally with a small number of participants, over short periods, with novel technology. A composite picture is beginning to appear from these trials of the benefits and issues for practice of mobile learning. Within the classroom, handheld response systems can be particularly effective if used to show a range of responses to open questions. New forms of collaborative learning can be enabled by handheld devices that enable a movement from individual responses, to small group consensus and then classroom discussion.

Students with personal mobile devices, ranging from phones to laptops, can gain rapid access to internet resources to support self-directed study, but personal ownership of technology is both motivating and disruptive. Schools, colleges and universities will no longer be able to justify expenditure on desktop computers when students have their own powerful tools. The challenge is to set guidelines for appropriate use and to provide tools and resources for personal learning that integrate with commercial applications.

Outside the classroom, it is becoming clear that mobile technology can support active learning in museums, galleries and outdoors. Audio is particularly effective, if used to enhance the environment and offer engaging narratives. Mixed-reality systems can augment locations with explorations, experiments and challenges for inquiry and game-based learning. At home and on the move students value the opportunity to gain rapid access to learning resources and to engage in non-formal learning, providing this is done through familiar tools and interfaces, while not trespassing on their online social space.

The new opportunity for mobile learning is to connect learning in formal and non-formal settings, so that inquiry learning in the classroom or lab can be continued in realistic settings, or that personal informal learning can be used as a resource for formal education. Personal and contextual technologies could enhance a lifetime of learning, but only if they are robust, unobtrusive and enhance rather than distract from everyday activity.

New personal and location-based technologies will raise significant ethical issues, such as whether schools and parents should continuously monitor children's learning outside the classroom and the rights and responsibilities of learners to bring personal tools and resources into school. Good practice will emerge from negotiation between teachers and learners, and from evidence of successful learning across a variety of settings and life transitions.

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