Mobile technologies: prospects for their use in learning in informal science settings

Eileen Scanlon, Ann Jones, Jenny Waycott

Scanlon, E., Jones, A. & Waycott, J. (2005).
Mobile technologies: prospects for their use in learning in informal science settings.
Journal of Interactive Media in Education 2005(25).
[jime.open.ac.uk/2005/25].

Published
22nd December 2005

ISSN: 1365-893X

Mobile technologies: prospects for their use in learning in informal science settings

Eileen Scanlon, Ann Jones,
Jenny Waycott

Abstract:

Recent developments in mobile technologies have offered the potential to support learners studying a variety of subjects. In this paper we explore the possibilities related to science learners and in particular focus on science learners in informal settings and reflect on a number of recent projects in order to consider the prospects for such work. The debate on informal learning acknowledges the complexity of the area and the difficulty of defining informal learning. One view is to consider the settings in which learning takes place as a continuum from formal settings, e.g. university, to social structures, e.g. friendship groups (Sefton-Green, 2004). The literature on science learning with mobile devices at this very 'informal' end of the spectrum is currently sparse and so in the paper we reflect on some projects and possibilities across the continuum. Our main focus is how mobile devices can support informal learning in science and research possibilities. Some of the recent research on mobile learning has used an activity theoretical perspective, including one of the case studies we discuss and in the final part of the paper we highlight the influence of activity theory in helping us to consider the complexity of the learning settings.

Keywords: Mobile technologies, informal learning, science education

Commentaries:

All JIME articles are published with links to a commentaries area, which includes part of the article's original review debate. Readers are invited to make use of this resource, and to add their own commentaries. The authors, reviewers, and anyone else who has 'subscribed' to this article via the website will receive e-mail copies of your postings.

Eileen Scanlon, Ann Jones, Jenny Waycott*, The Open University, UK.*

1 Introduction

This paper reflects on contemporary perspectives on science learning, together with the experience of a number of projects on mobile learning conducted at the Open University and elsewhere over the past few years, in order to consider possibilities of making productive use of mobile learning in informal science settings. However, there is very little literature, as yet, on the intersection of informal learning, science and mobile learning so in order to consider the possibilities for this area in the future we have therefore broadened our scope to include educational projects that are institutionally led (e.g. school projects), the use of mobile devices for leisure purposes (e.g. use in museums or for tourism), fieldwork and the potential for supporting hobbies.

There have recently been significant developments in mobile technologies, resulting in devices that combine telephone and wireless Internet connection with some of the functionality of personal computers. Many of these devices are described as handhelds or personal digital assistants (see Sharples, 2000). Handhelds have been described as *'flexible tools that can be adapted to suit the needs of a variety of teaching and learning styles'* (Curtis *et al*., 2002, p30).

Many definitions of mobile learning focus on harnessing such mobile devices for learning, e.g. Traxler (2005) comments that "*Mobile learning can perhaps be defined as 'any educational provision where the sole or dominant technologies are handheld or palmtop devices'*". However, as Traxler later points out, such definitions which are based around the technology can be problematic. Our approach to mobile learning, therefore, like Traxler and also in line with Sharples, Taylor and Vavoula (2005) is not to focus on the technology but on the learner being mobile. The important feature of mobile learning is that it is the learner who is on the move.

In this paper we will consider opportunities for using mobile learning in science settings, particularly for informal learning. As indicated above, given the paucity of literature as yet on very informal uses of mobiles in learning science, we will interpret these terms quite broadly and look across a range of settings in which learning can occur from formal settings such as schools or Universities to social structures such as friendship groups as well as outlining how hobbies might be supported.

First, however, we briefly consider some current perspectives on learning science.

2 Learning science

Until very recently, work on science learning has been influenced by a focus on the need to help learners develop conceptions of basic science concepts. The dominant perspective has been constructivism. Papers such as Driver *et al.* (1999) provide good summaries of the recent development in theories of learning applied to science reflecting a shift from the core commitment of constructivism 'that knowledge is not transmitted directly from one knower to another, but is actively built up by the learner' (p1). Driver points out that this core commitment is shared by a number of different traditions e.g. those focussing on personal construction of meanings, those focussing on apprenticeship into scientific practices and those looking at the way that learners are encultured into scientific discourses.

This constructivist perspective in science education with its different traditions has been dominant in the work on science education. How this perspective has resulted in implications for instructional practices has also been open to interpretation, but is often linked with the influence of practical experience and inquiry on learning (as in Millar and Linn's comments below):

> *Science should be taught in whatever way is most likely to engage the active involvement of learners and make them feel willing to take on the serious intellectual work of reconstructing meaning.*

(Millar *et al*., 2001, p 289)
and

> *Ideally science instruction will ensure that students learn complex science in the context of inquiry and have an experience of mastering new topics or technologies relevant to their personal needs or goals*

(Linn, 2004, p 9)

Contemporary models of science learning depend both on the acquisition and participation metaphor (see, Sfard, 1998). The acquisition metaphor is associated with traditional views of learning, where knowledge is acquired whereas the participation metaphor is concerned with more radical social theorising about the learner. Sfard has noticed the linguistic shift from talking about knowing rather than knowledge or concepts in much recent mathematics and science learning literature. The participation metaphor is useful for our consideration in the area of informal learning in particular, as using this metaphor shifts our ideas about knowledge from something we possess and learning from something to acquire to learning as something we do. She points out the importance of the linguistic shift from talking about knowledge (as something the learner possesses) to knowing which indicates action, and the consequence for our view of the learner as being interested in participation in certain kinds of activities rather than in accumulating private possessions.

This shift of view about the processes by which learning takes place is accompanied by changes in the way that science educators view what constitutes the components of good science understanding. Rather than simply concentrating on the development of difficult concepts, their scope now is to include the processes of science, and science for citizenship. That is there is a shift from viewing the key purpose of science learning in schools to be an apprenticeship for future professional life as scientists towards science for citizenship. This will have implications for our view of mobile and informal learning too, in relation to connecting to public accounts of science in museums or new media. The view of science understanding as an integral part of the real life world of students is also important. One of the consequences of this contemporary perspective on science curriculum and learning is that science educators are looking for ways to demonstrate the relevance of work in classrooms to science learners.

There are also views that the whole process of science learning should be better connected to the world outside the classroom. Sefton-Green argues:

Teachers and other educators just simply need to know more about children's experiences and be confident to interpret and use the learning that goes on outside the classroom ... we need a culture that can draw on a wider model of learning than that allowed for at present. Secondly we need to work within various curriculum locations to develop links with out of school learning experiences on offer.

(Sefton-Green, 2004, p 32)

3 The use of handheld devices for Science Learning

There is a synergy between what mobile technology can provide for learners and the needs of science learners in particular. In the previous section we discussed recent thinking about science learning and the different theoretical traditions that such thinking has drawn on. In considering mobile learning too there has been much discussion of these matters.

Informal learning is discussed in more detail in the next section, but it is worth noting here that much of the discussion about mobile learning also leads into a consideration of informal learning - because much mobile learning takes place outside traditional educational settings; see for example, Vavoula (2004). Some researchers would suggest there is a need for a new theory of learning to account for what we are seeing in these contexts; for example, Sharples, Taylor and Vavoula (2005) have recently argued that existing theories of learning are not sufficient to take mobile learning into account as they tend to assume that learning is classroom or home based - and even those existing theories that do consider learning outside the classroom do not consider the mobility of learners. Three facets of mobile learning are particularly significant. First, that learners are on the move, moving around physically but in other ways too, for example between devices and over time. Secondly a vast amount of learning that takes place outside formal learning situations and thirdly the ubiquitous nature of learning. Sharples (2005) suggests a conversational approach for a mobile learning framework or theory drawing on the work of Pask (1976).

In a previous paper Sharples (2003) describes the potential of mobile technology as providing for learners a 'pervasive conversational learning space' and says that the requirements for handhelds as personal learning devices include that they are truly portable, adapt to an individual's abilities, available anywhere and intuitive to use. These qualities map on very well to the view of science learning that we have described above. Mobility and portability have potential for making changes to the access to and interactions in science learning. These changes could address new concerns for science education in two distinct areas: (i) enhancing science communication and (ii) enabling collaboration in practical activities or fieldwork in science.

In relation to the first area, a key curriculum trend has been to engage learners with the prospect and problems of modern science as communicated in public. Curriculum trends, especially at school level, have been geared towards a new emphasis on science for citizenship in addition to the familiar view of science as an apprenticeship for future professional life as scientists. Science as it is reported in the news media, or science which emerges from museum visits are part of this public communication of science. There is work on learning from museums (e.g. Proctor and Tellis, 2003) and science museums e.g. the Exploratorium, (Fleck *et al*., 2002) and more recently work on accessing news reports from PDAs (Waycott, 2004) which demonstrate this potential.

The second consequence involves engaging students in what they regard as meaningful activity. The involvement of students in practical work and what role it plays in learning science has been much discussed. A key issue is whether the tasks set are authentic i.e. do they reflect the real work of scientists. For fieldwork, particularly in biology or earth sciences where fieldwork studies play a very important role in students developing their skills and understanding, there are many new possibilities opened up by use of mobile devices. For example, there are the advantages in terms of recording data or observations whilst on the move in the field.

Most contemporary science educators stress collaborative working and a dialogic perspective on learning, so collaborative working is a given in this setting. Computer supported collaborative learning (CSCL) offers the possibility of providing the essential conditions for the success of collaborative learning. According to Zurita and Nussbaum (2004) these conditions are '*the interactivity required to achieve shared goals; the enablement of discussions about the goals; the support of both individual and group outcome achievement; the coordination of participant roles and rules; and the synchronisation and sharing of tasks*.' However, still too often the assumption is that collaborative activities will involve students sitting at a PC. In early work at the OU reported later we noticed that there was a potential benefit of handheld computers in relation to the fact that as portable computers were in students' hands, they seemed to allow more spontaneous face to face communication than when students were seated round desktop computers (see Hennessy, 2000 and Hennessy *et al*., 2001).

The potential properties of mobility and portability offered by wirelessly networked handhelds in particular are under exploration (Danesh *et al*., 2001, Inkpen, 1999). Handhelds offer the possibility of a natural mobile collaboration environment with face-to-face interactions. Each individual student having their own handheld, has physical control over the hardware (unlike students 'taking turns' at a PC), and this helps to provide a necessary synchronisation and interactivity.

The unique affordances of handhelds include permanence, accessibility and immediacy as well as portability. This means that 'whether students are at home, in the classroom or beside a river, they can get what they need when they need it. They can get access to documents, data animations and software tools. They have access to work from earlier weeks.' (Staudt and Hsi, 1999). Staudt and Hsi also describe using handhelds to share information during collaborative tasks '. There are a number of studies looking at the use of mobiles for data gathering and field studies (Soloway 1999, Soloway et al., 2001).

4 Informal Learning in Science

So far, we have not discussed informal learning - and not surprisingly, defining informal learning is not straightforward but is the subject of continuous debate (see, e.g. Tough, 1971; Mocker & Spear, 1982; Livingstone, 2001; Hawkey, 2004; Sefton-Green, 2004; Vavoula 2004). What ***is*** agreed is that there is not a straightforward distinction between informal and formal learning. Many researchers in this area have suggested either a continuum between informal and formal learning, or matrices which include a number of dimensions. The particular features in the matrices differ, however.

Vavoula (2004) suggests that informal learning could be defined as a process of learning that occurs autonomously and casually without being tied to highly directive curricula or instruction. She presents a typology of learning based on the presence of, and control over, the goals and the process of learning. In intentional formal learning, the goals and the process of learning are explicitly defined by a teacher or by an institution. In intentional, informal learning, the goals and the process are explicitly defined by the learner. In unintentional, informal learning, the goals of learning are not specified in advance, and there is no prescribed learning process, but they can develop 'on the fly' as a learning occasion arises.

So deciding what counts as informal learning in science is an important question in our research. One issue for all researchers in this area is that there is little research, so far, on the 'very informal' end of the continuum: intentional, informal learning that is directed by learners, to fulfil their own goals and not connected to any formal institution. Given this, and the lack of clear distinction between formal and informal learning; it makes sense at this stage in the development of the field to also include what might be seen as more 'hybrid' kinds of learning: e.g. learning in museums and even learning in schools - but using approaches that are more informal than those normally used in the curriculum.

In the examples that follow therefore we look first at the use of mobiles in a classroom setting before extending the discussion to more informal settings.

4.1 Pocketbooks

A series of investigations of the use of portable devices was conducted at the Open University in the late nineties, beginning with the Pocketbook project, which followed the introduction of Pocketbook computers across a secondary school (Robertson *et al*, 1995). A later project the *Portable Information Technologies for Supporting Graphical Investigations* Project (see Hennessy, Fung, Scanlon and Northern, 1998; Hennessy, Fung and Scanlon, 2001; Hennessy 2000) involved a series of linked studies using early handhelds with adults, and school children in a range of settings. In one study, secondary school students were given handheld computers (Pocketbooks) to use in a collaborative project involving mathematics, science and geography skills. The work of 48 students aged 13-14yrs was tracked in 2 schools over 3 weeks. They were given a set of questions which resulted in them investigating the variation in weather patterns across the world. The questions were:

> How do weather patterns vary across Europe and locally during summer?
>
> Do temperatures vary with latitude?

Small groups of students (3-5) worked together to record weather pattern data and prepare graphs of their own results. They collected data from a variety of sources, using handhelds in a variety of locations. The data came from a remote sensing weather station, thermometers, newspapers, teletext, and the Internet. One key finding was that students each had access to their own learning materials on the handheld computer, and so maintained a sense of personal ownership over the data and project. Questionnaires measured students' attitudes pre and post intervention and students' belief that they could do work with computers was significantly increased. Students' graphing skills were significantly improved and they rated 'flexibility and use outside classroom' as the greatest benefit of using the pocketbook computers in this way.

4.2 Mobiles in a museum setting

Sefton-Green (2004) suggests that on a continuum from formal settings (such as universities or schools) through to informal settings such as social structures (families or friendship groups) organisations such as museums can be viewed as intermediate kinds of learning spaces. Certainly their visitors include both individuals who may or may not be pursuing particular learning goals and also students from schools and universities who may be working on particular projects as part of their curriculum.

One recent influential project reports on the experience of using handhelds at the Exploratorium, the original and groundbreaking hands-on science museum in San Francisco (Fleck *et al*.., 2002). The project investigated and evaluated ways of using handhelds to capture and record the trips of visitors to the museum. One key consideration was the importance of making sure that the devices used must not interfere with visitors' interaction with exhibits, and that social interaction is an important part of the Exploratorium experience. Fleck found that reading information panels beside exhibits distracted visitors, and so experimented with a 'Remember' device which records information about the exhibit visited and creates a visit record in the form of Web pages. A system was developed which provided a tag to be swiped on an exhibit that stored the appropriate URL on the user's visit record. This was also in response to the difficulty that visitors had in dealing with the provision of too many functions, and with the devices themselves which were '*Too large and fragile for users who want to experiment with the exhibits'.(p13)*

There are some similarities between this work and that reported by Proctor and Tellis (2003) and Proctor and Burton (2003) in relation to the piloting of mobile devices at the Tate Modern Art Museum in London. Although obviously this is not a Science museum, the study is nevertheless relevant to Science education. In a large scale pilot data was collected by questionnaire from 850 subjects who used iPAQ handhelds for a multimedia tour of part of the museum. A number of facilities were developed including location specific content delivery (material relevant to a particular exhibit being displayed as the visitor approaches it), a creative play facility (the possibility of choosing relevant soundtracks for an exhibit), an email facility (the possibility of sending canned messages to other visitors) and a polling facility to gauge response. As in the previously reported study there were difficulties experienced with the provision of too many facilities.

4.3 Mobiles in a field setting and the potential for amateur naturalists

The research studies cited above have focussed on visitors' use of mobile devices whilst visiting museums, but as Hawkey points out (2004); the number of physical visits to museums is exceeded by number of virtual visits to the museum web sites which provide a rich array of resources to support informal learning. Other organisations such as charities and special interest clubs are increasingly developing sophisticated web sites. Now that web sites can be accessed via smart phones and other mobile devices, such resources may help to meet informal learners' needs in particular areas of science, especially where some kind of fieldwork is involved. Amateur naturalists, for example, will often be moving around a habitat or several habitats to watch wildlife. The next section considers how such web sites could support the needs of informal learners.

The Royal Society for the Protection of Birds (RSPB) web site http://www.rspb.org/ for example contains a user-friendly database of UK birds which a learner can use to find out about habitat; identification and so on. Imagine that an amateur naturalist is walking their dog down by the river and spots a couple of birds of prey. She looks through the binoculars but is not sure whether they are kestrels or sparrow hawks (slightly less common in her area). She knows that kestrels hover and these birds are not hovering - so this suggests that they might be sparrow hawks - and their features seem to match what she knows about sparrow hawks. Then one of the birds begins to call. Accessing the RSPB's website allows her to check out the habitat of both species; see photos of the birds and comparisons of their identification features and most importantly, she can play a recording of the sparrow hawk's call which confirms their identification. Here the mobile technology brings the resources to hand to enable the learner to identify a species of bird and also to learn more about it whilst she is in the field. The learning project, in this case, is entirely directed by the learner, and how the learner records her experiences (or does not) is up to her.

The RSPB has also initiated another project, "BirdTrack", part of which aims to help bird watchers to keep track of their observations and at the same time contribute to a project on the migration movements of birds. It provides facilities for observers to keep and manage their records of their observations on a web site - and again this could be on a mobile device that they could use in the field. Projects such as this 'contribute to knowledge of birds and to their conservation at national, regional and local scales' (http://www.bto.org/birdtrack) and also support the informal learner in their organization: a need that has been recognized by the work of, for example, Corlett, D. *et al.* (2005); Vavoula and Sharples (2002); Vavoula and Sharples (2003).

One of the consequences of the contemporary approaches to science learning that we discussed earlier is the need for learning activities to be authentic. For example, it is important that learners engage in an activity which captures some of the essential features of what scientists do. Both these examples meet this criterion although they are examples of what informal learners CAN do, with existing devices and information. As yet, however, there is still rather little information about how learners on the ground make use of such information and technologies in their informal learning - and we will return to this briefly later. Before leaving our discussion of how mobiles can be used in fieldwork, however, there is further relevant research that should be mentioned which although not concerned with *informal* learning has implications for informal learning.

De Crom and Jager (2005) report on the use of PDAs in field trips as an alternative to conventional paper-based workbooks. In this study, information files were prepared by the lecturer before the field trip and transferred to the PDAs, which the learners then used both to download information and to take notes on during their fieldtrips. The learners were students taking an Ecotourism Management degree, many of whom will work as tour guides and who need to have a thorough knowledge of the natural history of the environments that they intend to visit. Resources on Biology were developed using WebCT for use on PDAs for use on the students' field trips, where conditions are often not suitable for note-taking or the use of books.

A pilot study involved two groups of learners, one of whom only used PDAs; had prior experience with using WebCT and online learning in Biology and also time to familiarise themselves with the PDAs prior to the field trip. The second group did not have this prior experience and were given the PDAs on the first day of the field trip in addition to a paper copy of the workbook. One of the main advantages reported was that learners could work in the field with just the one device: the PDA. They did not need to have textbooks, field guides or note books as everything they needed was on the PDA and this could be supplemented with other information (such as field guides) back at the camp. The students also worked collaboratively in obtaining additional information and verifying information and were able to access and consult information when and where it was needed, offering opportunities for authentic, just-in-time learning. Evaluation results suggested that the use of the PDAs enhanced learners' experiences and their motivation. Interestingly, in relation to the potential use of the RSPB website on bird identification, discussed earlier, the Birds multimedia programme was mentioned positively and enthusiastically in almost all the student feedback. Like the RSPB website it included bird calls which students found very helpful in their identification.

Mobile devices have also been used by professionals in their field work. The most well known study of this is research by Pascoe, Ryan and Morse (2000) who developed software tools for the mobile fieldworker for use with existing handheld devices and sensor technology. In particular they investigated the requirements of ethology fieldworkers for using PDAs in the field. They outlined requirements for mobile computer usage for fieldwork which included what they called "limited attention capacity": i.e. the device must allow the fieldworker's attention to be on his or her subject(s), (which in the case of animals and birds are also likely to be moving) rather than on using the mobile device. A key requirement is context awareness: location is particularly important and needs to be recorded: in many cases this might require plotting observations on to a map.

They also outline features of hardware which they consider necessary for field work carried out by ethologists and developed prototype programs based around these requirements and features which were used in a two month behavioural study of giraffe in which an ecologist replaced her paper notebook with the prototype for the two month period of her fieldwork. She was able to learn to use the system on the flight from England to Kenya (where the field work took place) and once in the field used her mobile device for observations including vegetation surveys, behavioural observation and giraffe faeces records. In general the prototype allowed the fieldworker to complete more work, and in less time, than would have been possible manually.

These last two studies illustrate the benefits that mobile devices can bring to Science field work, whether for students or professional scientists. As with most studies, they are not concerned with informal learning but as illustrated in the earlier bird watching scenario, many of the same advantages are available for informal learners. Going beyond science to the wider arena, Vavoula and Sharples's research (Vavoula and Sharples, 2002; Vavoula and Sharples, 2003) has documented informal learning practice and shown how it is organised, and Clough's work (2005) documents the wide range of informal learning that is supported by mobile devices. However, there is little as yet that focuses on informal learning in Science, so there is a need to investigate and document the experiences of learners in these kinds of settings.

5 An approach to understanding the use of mobile technology using Activity Theory

It is apparent from the range of examples reviewed above that the new settings in which mobile technology can be used are creating a new space for learning. Rather than being attached to constraints of time or place complex environments are being created by the mediation of technology. In the museum examples described above in section 4.2, the space inhabited by learners includes the physical space of the museum but also the virtual space which includes further electronic resources and the possibilities of learners interacting and collaborating with others both physically and virtually. The artefacts they interact with include physical paintings and installations as well as audiovisual resources on the mobile device, and of course the physical mobile device itself. While the work on science learning we reviewed earlier offers us useful concepts to consider in examining examples of learning (the idea of learning as participation in activities) there is a need to identify a framework which will allow us to consider complex settings in depth and understand how to track the impact of altering the learning infrastructure by introducing a mobile technology.

The space created by this set of resources we describe for museum settings is quite complex and therefore requires a different approach to understanding how learning occurs within it. Two challenges stand out - the need to understand how the complex setting functions to influence learning and how the mobile device itself is understood and adopted by users. Our view is that approaches based on activity theory give the best current accounts of this complex problem and activity theory is currently being applied to develop an understanding of human practice. It builds on the work of Vygotsky (Vygotsky, 1978; Vygotsky, 1987) and is a way of considering learning using three features- involving a subject (the learner), an object (the task or activity) and tool or mediating artefacts. The relationship between the subject and the object of an activity is mediated by a tool. Activity Systems is a development of Activity Theory (Engeström, 1987) and is used widely to understand organisations. Its central tenet is that human behaviour is situated within a social context that influences their actions. The meanings of actions are mediated by the rules of their community and the division of labour within the community influences the ways in which we behave. This approach can be applied to investigating settings involving the use of technology to mediate science learning.

Activity Theory does not form part of our earlier discussion of theories of learning in science as it is specifically a way of unpacking the influence of the setting (social and technological) on learning. Previous work has used Activity Theory and Activity Systems to conduct a retrospective consideration of several case studies including computer supported collaborative learning in science and the use of technology in a science postgraduate course taught in a distance education setting (Issroff and Scanlon, 2002). Waycott (2004) has developed an account of the way that mobile technology is appropriated by learners which clarifies the two way nature of the process- how new users appropriate mobile technology and integrate it to suit their own purposes and how in turn those technologies change the way learners do things, shaping both their actions and their environment. She uses concepts from Activity Theory to express this. The most important feature is the learner or user's objectives and the use of the computer to achieve them.

Drawing on her work on a number of studies of users of handhelds, Waycott looked at how participants differed in their expectation and evaluation of the device and the relationships between the design of the device and the activity it was expected to support. She looked at adults using handhelds in two workplace settings, studying on a distance learning course and visiting museums and art galleries. In the distance learning setting the focus was on the learners' use of e-books on the handheld PDA to supplement their use of other media some of which were static text. In the workplace setting, workers in the energy industry used mobile devices to access information while they were out of the office.

She conducted a small observational study of a one day visit to a Museum Art Gallery exhibit, where visitors used a PDA on their visit to the Landscape/Matter/Environment exhibit. The PDA contained background information in a variety of media about works on display, in addition to games, opinion polls and the possibility of communication with other visitors via standard text messages. (The communication facility was in response to research that indicated the importance of museum visits as social experiences. However it did not function successfully to replace the usual types of social interaction relying solely on specific messages such as 'I am hungry' or 'I am tired'). There were a number of findings in terms of the usability of such devices (regarded as more important in settings where the device is not owned by the user and therefore there is a limited period over which to learn about the interface.) The use of the PDA interfered with use of pen and paper for personal records which users were observed trying to use in conjunction with the device. Also she draws attention to the fact that the introduction of the PDA in this setting was unlike the other settings she studied. In the other cases she studied the PDA was introduced for a specific purpose whereas the introduction of the PDA in the gallery setting was in order to explore the possibilities and constraints.

In the Museum Art Gallery example the introduction of the mobile tool led to the following description of the process by which the activity was shaped:

> *The PDA introduced many possibilities and constraints to the activity of learning in the museum. The main possibility- the use of multimedia content appeared to enhance the activity, expanding the type of information available to visitors. The text messaging option, which it was hoped would also introduce a new possibility to the activity actually appeared to constrain, rather than enhance the activity. It did not successfully emulate the more dynamic and spontaneous verbal communication that museum visitors engaged in. Meanwhile the technical difficulties, novel interface and awkward means of carrying the tool also constrained the activity, causing temporary breakdowns and shifts in focus from the activity to the tool itself*

(Waycott, 2004, p 215)

For the analysis of this example we found the emphasis that Activity Theory places on tools, including computer based tools in the way activities are mediated very helpful. This shifts our attention away from simply the interaction between computer and to the activity as a whole. So, we found Activity Theory to be a productive approach useful in considering the above examples of the introduction of a mobile technology to the activity of a museum visit. The introduction of a mobile tool both changed the nature of the activity and suggested some changes to the design of the tool. There is a two way process by which the user adapts the tool they use according to their own preferences and past experience while the availability of the tool and its use leads to a modification of the activity that the user is engaged in. Waycott uses the term appropriation to mean the integration of a new technology into the user's activities. Waycott (2004) proposes a tool integration procedure which takes account of the shaping effect of technology on individuals and their social environment.

This is an example of a complex setting enhanced by mobile technology in which informal learning is likely to take place. Although the topic was not science learning, there are features of the setting which give some indications of similar possibilities and constraints being introduced in similar settings. In a Science setting, the difficulties in managing note taking would have been likely to be exacerbated by hands on activities. Discussions round exhibits would have been equally important for learning, and thus the participation metaphor and its emphasis on collaboration applicable here.

In the work described above we can see that the complexity of informal learning settings requires an approach to research that captures this complexity. In other work we have found that Activity Theory is a productive way to evaluate learning environments that are rich in technology (e.g. Scanlon and Issroff (2005) propose an Activity Theory augmented approach to evaluation).

6 Reflections

In this paper we have provided a review of existing work in a number of areas which suggest possibilities for the future of research on mobile learning in informal science settings. We reviewed the trends in contemporary science learning and identified a number of current trends which suggested that mobile learning in informal settings had particular benefits to offer. In particular we noted the view of learning as participation as an important metaphor which helps us to consider learning situations and the move to take science out of the classroom. So, the literature on learning in science suggests that mobile devices could play a significant role in extending the possibilities for people learning about science. By reviewing some current example of mobile use in science settings these possibilities were further illustrated. We noted the difficulty in adopting a secure definition of what is meant by informal learning but exploited the potential of the resultant unclear boundary descriptions and as a result we identify a need to build a conceptual framework to understand informal settings.

Finally we presented three brief case studies with a fourth presented in depth. The fourth case study identifies a role for Activity Theory and Activity Systems in particular, in extending the useful metaphors for exploring learning settings. The particular benefits of using Activity Theory to consider such settings are illustrated by the insights gained by the Waycott studies in terms of the tool appropriation and integration procedures.

obility and portability provide a communication channel between the technological wireless network and the social, face-to-face network, and mediate the social interaction of the participants. We need to understand how learning settings are changed by these new possibilities. Analytic frameworks (such as Activity Theory) and evaluation frameworks need to be applied to help us understand examples of the technology in use (see Issroff and Scanlon, 2001; Issroff and Scanlon, 2002). Waycott (2004) discusses a tool appropriation model and Taylor *et al*. (2006) a task model framework that is useful in this respect. Waycott's field studies (see e.g. Waycott *et al*., 2005) provide an example of how the approach to analysing settings in which the mobile learner operates using Activity Systems can provide insights, and remind us of the interactions between people, tools and their settings. Although we have not discussed them in any detail this paper there is also a body of work on the importance of design considerations for design of mobile devices, the potential of context aware devices (see e.g. Lonsdale et al., 2005) and the design of learning settings whether informal or otherwise.

However, Waycott does not discuss another aspect of Activity Theory which is used in interpreting settings where technology has been introduced. In his seminal work on health care systems, Engeström made the point that '*The primary contradiction in object of the doctor's work activity takes the form of patient as person to be helped and healed versus patient as source of revenue and profit'* (Engeström, 2003). This quote draws attention to the way that Activity Systems are particularly suited to the study of complex systems seen in their social and political context (see also, Scanlon and Issroff, 2005) and there are aspects of changes to the science curriculum and the introduction of technology to such settings that Activity Theory could be used to consider.

We need to conduct more case studies of users in informal science settings to explore these issues further, and we need to choose these from settings in which there is a continued emphasis on authentic tasks. One area in which more studies could be conducted is where people are using mobile devices as part of their daily lives.

7 References

Corlett, D., Sharples, M., Chan, T., and Bull, S. (2005) A Mobile Learning Organiser for University Students. *Journal of Computer Assisted Learning* June 2005 - Vol. 21 Issue 3, 159-237

Clough, G (2005) Informal Learning, PDAs and Mobile Phones. MSc Thesis, IET, Open University, United Kingdom

Curtis, M., Luchini, K., Bobrowsky, B., Quintana, C. and Soloway, E. (2002) Handheld Use in K-12: a descriptive account, *Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos,CA: IEEE Computer Society.

Danesh, A, Inkpen, K., Lau, F., Shu, K., Booth, K., and Geney, D. (2001) Designing a collaborative activity for a Palm handheld computer. In *Proceedings of CHI, Conference on Human Factors in Computing Systems*, Seattle, USA, April

De Crom, E. P. and de Jager, A. (2005) The "ME" -Learning Experience: PDA Technology and E-Learning in Ecotourism at the Tshwane University of Technology (TUT). Paper presented at M-Learn 2005, (October) Cape Town, South Africa. Available at: http://www.mlearn.org.za/papers-full.html (accessed 21/12/2005)

Driver, R., Leach, J., Asoko, H., and Scott, P. (1999) Constructivism in science education, *Educational Researcher*, 23, 7, 5-12

Engeström, Y (1987) *Learning by Expanding: an Activity Theoretical Approach to Developmental Research*. Helsinki

Engeström, Y (2003) http://www.edu.helsinki.fi/activity/pages/chatanddwr/activitysystem/ last accessed 21/12/05

Fleck, M., Frid, M., Kindberg, T., O Brien-Strain, E., Rajani, R., and Spasojevic, M. (2002) From informing to remembering: ubiquitous systems in interactive museums, *Pervasive Computing*, 1(2), 13-21

Hawkey, R. (2004) Learning with Digital Technologies in Museums, Science Centres and Galleries; A Report for NESTA Futurelab (no 9); available at http://www.nestafuturelab.org/research/reviews/09_01.htm (last accessed 26/08/05)

Hennessy, S, (2000) Graphing investigations using portable (palmtop) technology, *Journal of Computer Assisted Learning*, 16.243-258

Hennessy, S., Fung, P., Scanlon, E., and Northern, L. (1998) Graphing with palmtops, *Micromath*, 14,2,30-33

Hennessy, S., Fung, P. and Scanlon, E. (2001) The role of the graphic calculator in mediating graphing activity *International Journal of Mathematics for Education in Science and Technology*, 32(2) 267-290

Inkpen, K., (1999) Designing handheld technologies for kids, *Personal Technologies Journal*, Vol 3 (1&2) 81-89

Issroff, K., and Scanlon, E (2001) Case studies revisited- what can Activity Theory offer? In Dillenbourg, P. (ed) Proceedings of First Euro-CSCL Conference, Maastricht

Issroff, K., and Scanlon, E. (2002) Using technology in higher education: an activity theory perspective, *Journal of Computer Assisted Learning*, 18.77-83

Linn, M. (2004) Using ICT to teach and learn science. In Holliman, R. and Scanlon, E. *Mediating Science Learning through Information and Communications Technology* London, Routledge Falmer

Livingstone, D.W. (2001) Adults' Informal Learning: Definitions, Findings, Gaps and Future Research. NALL Working Paper No.21, CSEW, OISEUT, University of Toronto, Canada.

Lonsdale, P., Beale, R., and Byrne, W. (2005) Using context awareness to enhance visitor engagement in a gallery space. In People and Computers XIX: the bigger picture, Proc. HCI 2005, London Springer
Millar, R. Leach, J. and Osborne, J. (2001) *Improving science education: the contribution of research,* Open University Press
Mocker, D.W., and Spear G. E. (1982), *Lifelong Learning: Formal, Nonformal, Informal and Self-Directed*, *Information Series* No. 241, Columbus: ERIC Clearing House on Adult, Career and Vocational Education, The Ohio State University, (ERIC Document Reproduction Service No. ED 220 723).
Pascoe, J., Ryan, N., and Morse, D. (2000). Using while moving: HCI issues in fieldwork environments. *ACM Transactions on Computer-Human Interaction, 7*(3), 417-437.
Pask, G. (1976) *Conversation Theory: Applications in Education and Epistemology*. Amsterdam and New York. Elsevier.
Proctor, N., and Burton, J. (2003) Tate modern multimedia tour pilots 2002-2003, In J. Attewell, G. Da Bormida, M. Sharples and C. Savill-Smith (Eds.) *M Learn 2003: Learning with mobile devices* (pp 54-55)London: Learning and Skills Development Agency
Proctor, N., and Tellis, C. (2003) *The state of the art in museum handhelds in 2003*. Retrieved May, 2004 http://www.archimuse.com/mw2003/papers/proctor/proctor.html
Robertson, S.I., Calder, J., Fung, P., Jones, A., and O'Shea, T. (1995) *The use of Pocketbook computers in education,* CITE Report, No 217, Open University Internal Report
Scanlon, E., and Issroff, K. (2005) Activity Theory and Higher Education: evaluating learning technologies, *Journal of Computers and Learning*, 20 (6) 430-439
Sefton-Green, J (2004) Literature Review in Informal Learning with Technology Outside School; A Report for NESTA Futurelab (no 7); available at http://www.nestafuturelab.org/research/reviews/07_01.htm (accessed 26/08/05)
Sfard, A. (1998) On two metaphors for learning and the dangers of choosing just one, *Educational Researcher*, 24 (7) 5-12
Sharples, M. (2000) The Design of Personal Mobile Technologies for Lifelong Learning. *Computers and Education*, 34, 177-193.
Sharples, M. (2003) Disruptive Devices: Mobile Technology for Conversational Learning. *International Journal of Continuing Engineering Education and Lifelong Learning*, 12, 5/6, pp. 504-520.
Sharples, M. (2005) Learning as Conversation: Transforming Education in the Mobile Age. *Paper presented at Conference on Seeing, Understanding, Learning in the Mobile Age,* Budapest, Hungary, April 2005.
Sharples, M., Taylor, J., and Vavoula, G. (2005) Towards a Theory of Mobile Learning. *Proceedings of mLearn 2005 Conference*, Cape Town.
Soloway, E. (1999) Science in the palms of your hands *Communications of the ACM* 42(8),21-27
Soloway, E., Norris, C., Blumenfeld, P., Fishman, B., Krajcik, J., and Marx, R. (2001) Logon education: handheld devices are ready at hand, *Communications of the ACM*, 44(6),

15-20
Staudt, C. and Hsi, S. (1999) Synergy projects and pocket computers http://www.concord.org/library/1999spring/synergyproj.html
Taylor, J., Sharples, M., O'Malley, C., Vavoula, G., and Waycott, J., (2006) 'Towards a Task Model for Mobile Learning: A Dialectical Approach', to appear in *International Journal of Learning Technology*, Special Issue: 'Interactions, objects and outcomes in learning', eds. P. McAndrew and A. Jones,
Tate Modern (2003) Tate Modern Multimedia Tour. Retrieved January 21st, 2004 from http://www.tate.org.uk/modern/multimediatour/artworks.htm
Tough, A. (1971) *The Adult's Learning Projects: A Fresh Approach to Theory and Practice in Adult Learning.* Toronto: OISE Press
Traxler, J. (2005) Mobile Learning: It's here but what is it? http://www2.warwick.ac.uk/services/cap/resources/interactions/archive/issue25/traxler/ (last accessed 20/12/2005)
Vavoula, G., and Sharples, M. (2002) Requirements for the Design of Lifelong Learning Organisers. *Proceedings of MLEARN2002, European Workshop on Mobile and Contextual Learning*, Birmingham, UK, pp. 23-26.
Vavoula, G., and Sharples, M. (2003) Putting order to episodic and semantic learning memories: the case for KleOS. D. Harris, V. Duffy, M. Smith & C. Staphanidis (eds.), *Proceedings of HCI 03 Conference*, Vol 3. Crete, June 22-27, Lawrence Erlbaum Associates, pp. 894-898.
Vavoula, G. (2004) KLeOS: A Knowledge and Learning Organisation System in Support of Lifelong Learning. PhD Thesis, University of Birmingham, UK
Vygotsky, L.S. (1978) *Mind in Society: the Development of Psychological Processes, Cambridge, MA: Harvard University Press*
Vygotsky, L.S. (1987) *The collected works of L.S.Vygotsky,* Plenum Press
Waycott, J. (2004) The appropriation of PDAs as learning and workplace tools: an activity theory perspective, Open University Ph D thesis
Waycott, J, Jones, A. and Scanlon, E. (2005) Using a PDA as a learning or workplace tool, *Learning, Media and Technology* , 30(2) 107-130
Zurita, G. and Nussbaum, M. (2004) Computer supported collaborative learning using wirelessly interconnected handheld computers, *Computers and Education,* 42, 289-314