Informal learning with PDAs and smartphones

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Abstract

There has been increasing interest in informal learning in recent years alongside interest in how such learning can be supported by technology. However, relatively little is known about the extent to which adults make use of their own mobile devices to support informal learning. In this study, a survey was used to investigate whether, and to what extent, experienced users of mobile devices use their mobile devices to support intentional informal learning. If so, do they make use of mobile device connectivity to support opportunistic informal learning and does such connectivity support or encourage collaborative informal learning? Experienced mobile device users were recruited from web forums and business, and asked whether they used their devices to support informal learning. A pattern of learning uses emerged, some of which deployed the mobile device capabilities relatively unchanged, others triggered adaptations to typical learning activities to provide a better fit to the needs of the learner. These informal learning activities provided the basis for the design of a flexible mobile learning framework that can be extended to support developments in mobile technology, and increasing use of Web 2.0 technologies by informal learners.

Introduction

In March 2006, the Ofcom report on adult media literacy (Ofcom 2006) found that 82% of UK adults owned a mobile phone. In China, mobile phone ownership had already exceeded landlines by 2004, (BBC News 2004) and by 2007, this trend was being repeated in other countries throughout the world (Central Intelligence Agency 2007). With such near-ubiquitous market penetration, mobile devices have attracted the attention of researchers and educators through their potential both as learning tools that support and enhance the learning experience (Chang *et al*. 2003; Zurita & Nussbaum 2004) and as disruptive devices with the potential to interrupt and distract (Selwyn 2003; Mifsud 2004; Syvanen *et al*. 2004).

Handheld devices have been deployed as learning tools in both formal and informal learning contexts, with learners of all age groups. In the formal school context, personal digital assistants (PDAs) have been used in teaching both within the classroom setting (DiGiano *et al*. 2003) and outside in fieldwork (Chen *et al*. 2003). The potential of mobile devices to support adult learning has been explored through the introduction of handhelds as interactive museum guidebooks (Hsi 2003), as resources to provide access to contextually relevant information to medical students (Smørdal & Gregory 2003) or as a formative assessment tool for nurses (Kneebone *et al*. 2003).

Although there has been research on how mobile devices can support and enhance collaborative learning in a variety of contexts, (e.g. Hennessy 2000; Hoppe *et al*. 2003; De Crom & De Jager 2005; Walker 2006; Roschelle 2003), there is relatively little literature on whether and how such devices are used for collaborative learning in the pursuit of learners' own goals.

The introduction of mobile technology to a group of learners unaccustomed to that technology has sometimes highlighted the disruptive potential of the technology. Kneebone *et al.* (2003) found that some participants expressed anxiety about the process of using the PDAs which, they felt, might have been improved had they more experience with the technology. Other researchers uncovered a recurrent theme of usability problems linked to small screen size (Waycott 2004) or difficulty entering data into the device (Smørdal & Gregory 2003). Yet, Simms Parr *et al.*, (2004) assessed the effect of practice on the accuracy with which children entered data on a PDA and discovered that their skill levels improved with practice (43% accuracy in post-test compared with 29% in pre-test). This suggests that some of the problems described by participants may have been reduced or eliminated had they acquired more experience with mobile technology.

The study described in this paper therefore targeted participants who were already experienced and enthusiastic mobile device users. Sampling from a group who were already comfortable with using mobile technology minimized the anxiety and usability problems described in previously cited studies, and improved the chances of uncovering genuine instances of informal learning using mobile devices.

Participants were asked about their informal learning, and in particular, about informal learning in which they used their mobile devices. Informal learning was identified as an important social phenomenon in as early as the 1970s (Tough 1979). Since Tough's research, the informal learning activities undertaken by adults has attracted the attention of other researchers such as Sefton-Green (2004); Livingston (2006); Sharples *et al.* (2007); Roschelle (2003).

But what constitutes informal learning? There is some debate over this question. Schugurensky describes informal learning as a loose category that encompasses any forms of learning that are neither formal nor non-formal (short courses, workshops, professional development) (Schugurensky 2006). According to Tough (1979), an informal learning project '. . . is simply a major, highly deliberate effort to gain certain knowledge and skill (or to change in some other way)'. Livingston (2000) defined informal learning as '. . . any activity involving the pursuit of understanding, knowledge or skill which occurs outside the curricula of institutions providing educational programs, courses or workshops'. By 2006, Livingston had refined his definition of informal learning to include 'all forms of intentional or tacit learning in which we engage either individually or collectively without direct reliance on a teacher or externally organized curriculum' (Livingston 2006). He referred to these forms of learning as 'self-directed or collective informal learning', and highlighted the fact that unintentional or tacit informal learning has been relatively underestimated or ignored. Vavoula *et al.* (2005) created a typology which categorized learning according to whether and by whom the goals and processes of learning were defined (see Fig 1).

Vavoula's typology subdivides the intentionality embedded within the learning activity into two areas of control:

1 Control over the process of learning, that is, the tools and methods used to learn.
2 Control over the goals of learning: the expected learning outcome, if there is one.

In highlighting the areas of control, Vavoula's typology clarifies the distinction between formal and informal
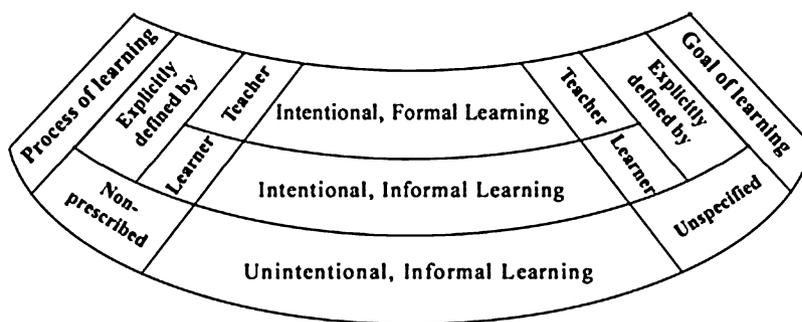

Fig 1 Typology of informal learning (reproduced from Vavoula *et al.* 2005).

learning and includes a category for unintentional or tacit informal learning. However, it does not distinguish between different types of learning process choices a learner or teacher may make. These choices include not only whether and how to deploy the various learning tools available, but also how to engage with both the social and the physical contexts of the learning they are undertaking. Additionally, learners decide whether and how to collaborate with other learners, to pool and share resources, or simply engage in individual reflection.

Mobile devices, such as PDAs and Smartphones, may be used as tools to support the learning (process of learning). In addition, they may also support new ways of learning in a mobile context that were previously difficult to achieve. In his study exploring the potential of wireless mobile devices to support learning, Roschelle (2003) highlighted the need for research to identify the relationship between mobile technologies and the 'desirable social practices of learning'. In this study, we analysed the mobile learning practices of informal learners in order to develop a functional mobile learning framework that not only reflects current informal mobile learning practices, but also identifies potential mobile learning scenarios made possible by technological developments in handheld technologies.

To identify informal mobile learning practices, we looked for instances of informal learning where the learners had chosen to use mobile devices. In the absence of a formal, externally imposed learning framework, informal learners will tend to use whatever techniques, resources and tools that best suit their learning needs and personal preferences (Tough 1979). Research into learning scenarios has uncovered a number of ways in which mobile devices can be deployed to support the learner, for example, Pinkwart *et al.* (2003) explored how PDAs could be used in cooperative learning, Kukulska-Hulme and Traxler (2005) used a selection of case studies to explore the issues surrounding modern networked mobile learning, and Naismith *et al.* (2006) reviewed the literature on a range of mobile learning initiatives. Given the evidence that mobile devices have a role to play in formal learning scenarios, it seemed reasonable to expect that experienced mobile device users would include their mobile devices among the learning tools they used to support their informal learning. This led to the first research question: 'Do mobile device users use their mobile devices to support intentional informal learning?'

Unanticipated learning opportunities may also present themselves, for example, an unusual bird may land nearby during a walk in the country or a rare type of traction engine may rumble past. Therefore, we also asked 'Do informal learners use their mobile devices to convert unforeseen events into informal learning occurrences, for example, by accessing situated content or contacting others with expert knowledge?'

Modern mobile devices offer powerful connectivity. This connectivity supports not only contextual access to information, but also synchronous (telephone conversation, Voice over IP, messaging) and asynchronous (web forums, blog entries, email, txt messaging) communication with others. Given the potential for collaboration afforded by the devices (DiGiano *et al.* 2003; Roschelle, 2003; Facer *et al.* 2004)), we also asked 'Does the mobile connectivity available with mobile devices such as PDAs and Smartphones encourage or support collaborative informal learning?'

Methods

The study described in this paper targeted PDA and Smartphone enthusiasts as the community are most likely to be using their mobile devices in informal learning. Participants were recruited from the active community of web forum users. Web forums are Internet-based, asynchronous discussion groups that are aimed at people who share a specific interest; in this case, PDAs and Smartphones.

Both qualitative and quantitative data were needed to answer the research questions. Facts about whether the respondent had a Smartphone or PDA, which features they used, and their age, gender and occupational status were needed to help classify the participants and identify usage trends. Qualitative details about how participants used their mobile devices to support their informal learning helped broaden our understanding of the potential of mobile devices as aids to learning, and provided learning case studies which could be compared with previous mobile formal learning scenarios. As mobile learners are, by their nature, mobile and geographically dispersed, it was impractical to use a data-collection method that involved direct observation or contact. Therefore, a web-based survey was selected as the most appropriate method to allow participants to provide information about their practices and experiences. Also, as PDA and Smartphone users may

be located anywhere in the world, a web-based survey gave access to a wide pool of participants.

The study was conducted over a 4-week period. A message was posted in five PDA and Smartphone forums inviting participants to take part in the web survey and providing a link to the survey pages. Three businesses also agreed to circulate email invitations to their employees. The forum messages and email invitations generated over 200 responses of which over 100 provided details of informal learning with mobile devices. The results suggest that mobile devices are used extensively in an informal learning context by enthusiasts, and that they use them in ways that correspond to the collaborative, contextual and constructivist mobile learning philosophies identified by Patten *et al.* (2006).

The gender split of the participants was 85% male, 15% female. Table 1 shows the age breakdown of the sample.

The low number of under-18s probably reflects the make-up of the typical web forum user or business employee (the sources of the sample). The higher response rate in the 30 to 39 age group broadly matches the Ofcom Report findings (Ofcom 2006) that ownership peaks (95%) in the 24 to 34 age range.

The majority of the sample were employed, with 77% in full-time paid employment and 10% in part-time paid employment. The remaining 12% were either not in paid employment or doing unpaid or voluntary work. None of the sample were retired. Participants were asked whether they engaged in any formal learning activities, including full- and part-time campus-based education, distance learning, day or evening classes and work-related training. Participants could select more than one response, and 72% reported that they took part in some form of formal learning, with 65% engaging in formal work-related training.

Quantitative questions were included to try to establish the level of enthusiasm felt by participants towards their mobile devices. For example, the question 'How important is your mobile device to you' used a 5-point Likert scale to assess the significance attached to the mobile device, to which 67% of participants selected the most positive response of 'I keep it with me all the time and would feel lost without it'.

To discover the relative frequency of common activities undertaken using a mobile device, respondents were given a list of typical activities and asked to rate the frequency with which they did them on a Likert scale of 1 = daily, 2 = weekly, 3 = occasionally, 4 = never and 5 = not applicable. Participants could select only one answer, for example, they could choose either daily or weekly but not both. Table 2 illustrates the responses received ($n = 154$):

The column entitled Cumulative daily + weekly contains the percentage who responded 'daily' plus the percentage who responded 'weekly'. Responses of 'Occasionally', 'Never' or 'Not Applicable' are not included. The three most frequently cited activities are writing notes, reading e-books and using the Web. These responses indicated that this population employed their mobile devices extensively and illus-

Table 1. Participants (%) grouped by age.

Age of participants				
Under 18	18–29	30–39	40–49	Over 50
2	25	39	22	12

PDA/smartphone activity	Percentage of PDA/Smartphone users doing activity		
	Cumulative daily + weekly	Daily	Weekly
Write notes	70	47	23
Browse the Web	45	21	24
Read e-books	42	20	22
Photos: storing, viewing or sharing	41	18	23
Read web forums	33	18	15
Take photos	23	6	17
Record audio	14	1	13
Write applications	14	9	5

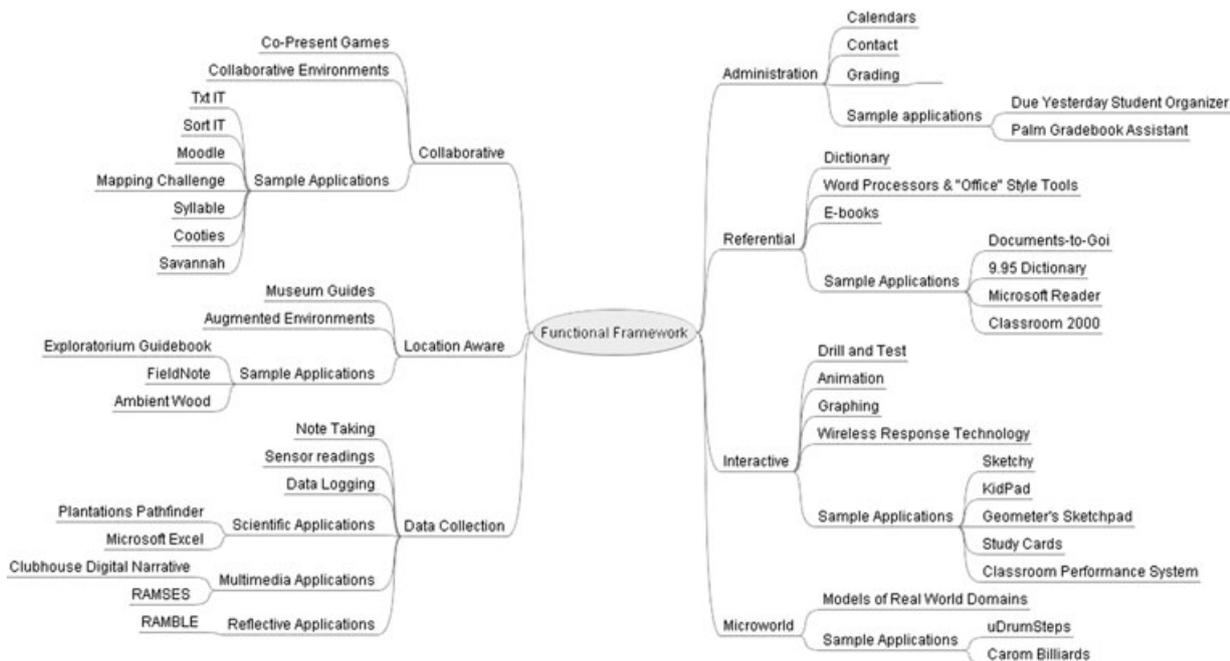Table 2. Frequency of typical PDA and Smartphone activities.

Fig 2 Mobile learning functional framework (Patten *et al*. 2006).

trated the range of device features and applications that they used.

Participants were also asked to provide qualitative, textual detail about informal learning with their mobile devices. These responses were sometimes quite lengthy and provided the greatest insight into how enthusiastic mobile device owners deployed PDAs and Smartphones to support informal learning.

Analysis framework

Initially, an existing framework was used; a functional framework for categorizing *formal* mobile learning applications, developed by Patten *et al*. (2006) and reproduced in Fig 2.

This framework categorized handheld applications according to their practical use and the pedagogical theory on which they were based. It subdivided mobile learning applications into seven categories representing the pedagogical function of the application: collaborative, location aware, data collection, administration, referential, interactive and microworld. It then analysed each application in terms of its function and combined these two perspectives into a single framework. Patten *et al*. (2006) proposed that 'the most educationally appropriate applications currently available are built on

a combination of collaborative, contextual, constructionist and constructivist principles' and concluded that the three categories data collection, location aware and collaborative are particularly suited to learning with handheld devices provided they are informed by collaborative contextual and constructivist learning theories.

This framework provided the initial basis for analysing the informal learning activities undertaken by the mobile device users in this study. However, further analysis revealed that many of the informal learning activities reported by the participants did not fit neatly into this model. Some appeared to span two or more nodes of the framework. Others did not readily fit into any. For example, downloading information from the Internet for use on the mobile device could be viewed as a referential activity. However, if this information was downloaded using mobile connectivity in response to a situated need, then it fitted more readily into the location aware category. The Patten *et al*. (2006) framework was designed to help analyse learning applications that could be loaded onto a mobile device; therefore, the effects of mobile Internet connectivity were only covered in the collaborative category, where wifi-supported applications such as Savannah (Facer *et al*. 2004) were listed. This contrasted with the activities reported by the
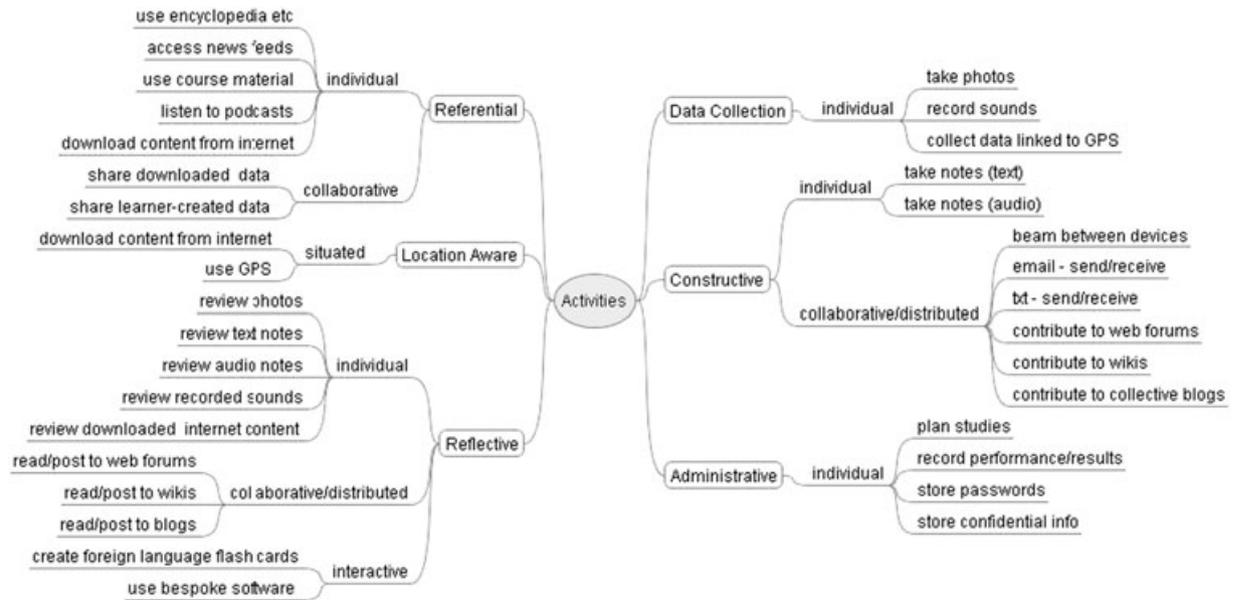
Fig 3 Informal mobile learning framework.

participants in this study who used all the mobile connectivity options available (beaming, wifi and GPRS) to support collaboration in a variety of contexts. It was therefore necessary to adapt the framework.

The learners seldom used pre-designed mobile learning applications; instead, they deployed their devices in ways that were appropriate to their current physical and temporal context and learning needs. Sharples *et al.* (2007) proposed criteria for a theory of mobile learning which took account of the underlying assumption that mobile learners are continually 'on the move', extending the concept of mobility to encompass not only geographical mobility, but also mobility between learning topics, contexts, and ideas and strategies for learning. The participants in this study demonstrated a high degree of creative mobility in the ways they used their devices and adapted both the device use and their learning strategies to suit their needs.

To cater for the variety of ways that participants engaged with their mobile learning environment, we adapted the Patten *et al.* (2006) functional framework as shown in Fig 3. The main pedagogical categories were reorganized to reflect the type of mobile learning activity that was evident in the data, and the categories of collaborative and interactive were transformed into qualifiers that could be applied to the mobile learning activities to reveal more details about the learning.

Additional qualifiers were added as required. The main categories are referential, location aware, reflective, data collection, constructive and administrative. Five qualifiers were identified: individual, collaborative, situated, distributed and interactive. The informal learning activities reported by the participants are listed against the categories and qualifiers that characterize them. For example, having collaborative as a main category in the original framework was problematic because participants also collaborated in the other categories. Re-designating collaborative as a qualifier allows for more flexibility in categorizing a range of collaborative activities.

Referential activities

In the Patten *et al.* (2006) framework, referential applications deployed the portability and mobility of hand-held devices to provide access to content where learning activities occur. Learning activities categorized as Referential in the Informal Mobile Learning Framework in Fig 3 also involve accessing material using the PDA and provide concrete examples of informal learning activities that make use of the sample referential applications (e-books, dictionaries etc) described in Patten *et al.* (2006) framework. For example, 42% of participants read e-books on a daily or weekly basis.

Participants used the Web to support their informal learning projects, transferring content to their PDA or Smartphone for use when away from the PC, with 99% synchronizing their mobile devices with their PC. These informal learning activities were generally planned in advance. Learners would identify a period, say a train or plane journey, when they had time to spare and would download or prepare reference material on their device for use during these periods.

Podcasting was also identified as a source of audio learning material for the device, making use of a different communication channel for learning: 'Downloading and listening to podcasts about PalmOS handhelds'.

Nine participants (6%) gave detailed text examples of how they used tools, such as Avantgo, Plucker and News feeds, to download information in a format that was tailored to display well on the smaller mobile device screen. Information downloaded ranged from informative resources, such as news and weather, to collaboratively created reference information from Wikipedia.

> I use it to download papers that I may be interested in from specialist apps (Merck Medicus Mobile, Avantgo etc) and from RSS feeds. This is automated every morning and I check it all on the train to work.

Location aware activities

Location aware applications are described in Patten *et al*. (2006) as those which present appropriate referential information or encourage device users to explore their environment. In the sphere of informal learning with the development of global positioning system (GPS)-enabled mobile devices with high levels of connectivity, the potential for learners to interact with their environment is expanding. At the time of the study, connected GPS-enabled mobile devices were not widely available; nevertheless, eight participants did mention GPS with reference to informal learning. Those without GPS incorporated an awareness of the physical context into their learning by using mobile connectivity to connect to the Internet and selectively search for referential information relevant to their location.

Individual location aware activities
When asked to describe informal learning activities involving their mobile device, eight participants provided details about how they downloaded material related to a specific context. For example, they would research in advance of a planned visit or project and load the information on their mobile device to be on hand when needed, for example:

> Downloading museum, zoo or aquarium tour narrative and expanded exhibit information either in advance or onsite.
> Researching information on locations I intend to visit on holiday.

This deployment of mobile devices to store reference material for use when sightseeing provides an interesting parallel to formal research scenarios such as the electronically guided museum visits (Hsi 2003).

Those with mobile connectivity would download information at the point at which it was needed, often researching subjects of interest at the time the interest was triggered:

> I learned the history of soft drinks after checking who owned 7-UP during dinner. I learned about the Ironman Triathlon after watching the Tour de France. I looked up the greatest cowboy in the world after seeing something on TV (Ty Warner). Whenever a question comes up somewhere, I whip out my PDA and look it up.
> I also frequently look things up with Google if something piques my interest, e.g. finding out about a band I hear, or about a place I saw on TV.
> I do a lot of informal learning through wikipedia.org (and that includes using it on my smartphone). I may be thinking about a subject and then I can quickly get out my phone and look the subject matter up on the internet.

Collaborative location aware activities
A collaborative element was implicit in descriptions of location aware activities, and two participants described this collaborative intent explicitly, describing how they downloaded material onto their device in order to share it with others:

> Downloading web sites and other documentation to have while out with family for reference.
> Learning about animals as the zoo where I volunteer to be able to pass information on to visitors.

Reflective activities

Reflective activities are fundamental to learning, but reflection does not take place in isolation. Learners

reflect on something, a phenomenon or artifact they have encountered whether they have created it themselves or it was created by others. Most learning activities involve a reflective element; however, 28% of the participants in this study specifically highlighted the ways in which mobile devices added an extra dimension to their reflective activities in their responses to the free text questions. They described interacting with and reflecting upon material that was local to their mobile device (such as notes or images they created) as well as reflecting and interacting with material that resided elsewhere (such as web pages, wikis, forums or blogs). Reflective activities fell into four interaction types; however, all the collaborative reflective activities were also distributed, so these two categories were combined, leaving the following categories:

- Individual reflective activities
- Collaborative/distributed reflective activities
- Interactive reflective activities.

Individual reflective activities

Individual reflective activities described by participants involved reviewing content downloaded or created on the PDA. The following examples are typical of responses that described returning to material on the PDA at a later time in order to engage in further related activities. These activities involve manipulating the data, revising it in some way, or following up existing information with further research. For example:

> I write notes all the time then follow them up on internet when I have time.
> Making notes, keeping information with me so I can revise it often, e.g. talk notes.
> Stories I'm working on.
> Make notes that you will follow up later from conferences and presentations.
> Using Avantgo to look at relevant sites. Making notes as if using a dictaphone to follow up later.

Collaborative/distributed reflective activities

When asked how often they used their mobile device to read messages on web forums or conferences, 18% selected daily and 15% weekly. In their free text descriptions, they provided details of collaborative reflection, including reading and contributing to group information resources, such as wikis, web forums and group blogs:

> I regularly contribute, also, to Palm PDA forums (at www.1src.com); again to learn from others and also to add my own experience to the community's knowledge.

Interactive reflective activities

Some participants went to considerable lengths to adapt the functions provided by their device to suit their immediate learning needs. They would explore the range of mobile resources available to them through their device, combining them in order to enrich their learning experience, for example:

> Multiple glossary dictionaries can combine with e-book reading software and bookmarking and note-taking utilities in a way unmatched outside the PDA realm.

Where software that would support their learning was available, informal learners made use of it. Applications included wine tasting and charting software, applications for tracking diet and fitness and astronomical charting software. The backlit PDA screen was described as an advantage for nighttime learning activities, for example:

> I use my PDA to help with my new hobby of astronomy as it has excellent reference resources and with its backlight it works great in the dark.

Where the software was not available, some learners were prepared to adapt existing applications, or produce new applications themselves. One participant devised an ingenious way to combine the notes application and the voice-recording in order to support his language learning.

> I make flashcards using the notes application. To do this, I first write out the question or 'front side of the flashcard' on the note. Then I make a recording of the 'back side of the flashcard' and put a link to the recording right next to the first part. Then, you look at the first part, say your answer, then check it with the voice recorded correct answer.

Another participant described:

> Writing an onboard compiler . . . and most of my applications directly in my device, as a hobby and a never ending learning process in programming knowledge. The ultimate knowledge being for me to write a compiler (an application to build other applications).

Many mobile device users do not have this level of expertise, but it seems that acquiring a mobile device can trigger device-related learning.

Data-collection activities

Data collection, as used in this interpretive framework, refers to the use of mobile devices for recording data and information about the environment and maps broadly onto the Data Logging and Sensor Readings applications described in the Patten *et al.* (2006) framework. Such activities might include mass observations, such as the BBC's snailwatch or the RSPB's Big Garden Birdwatch, in which the data collected by individuals are combined with the observations of others to produce an information database which may provide further learning opportunities. However, only one participant described collecting and collating data in this way:

> . . . we collected info on separate PDAs and beamed them to one – that user collected their results in a HanDBase database to share with everyone . . .

The audio-recording facility was used on a regular basis by 14% of participants. Two provided more details in their free text descriptions, with one describing 'recording sounds for later identification' and another 'using my voice recorder to record magic lectures'.

The cameras on mobile devices were used by 23% of participants on a daily or weekly basis. Three participants gave detailed descriptions of the ways in which they used the device camera to support their learning, for example:

> Take pictures of diagrams, models and participants to aid retention of knowledge from a workshop/seminar or pictures of electronic components showing connection layouts.

The number of participants who provided free text descriptions of learning activities that used the camera was relatively small. However, when the study was conducted, 45% of the participants did not have a built-in camera on their mobile devices. Now that cameras are commonly provided with most PDAs and Smartphones, they are more likely to be used to support informal learning projects.

Constructive activities

The constructive category refers to activities in which the learners create or construct knowledge, either alone or in concert with others. It involves the mobile device users interacting with the surrounding context in order to generate some form of learning output. For example, recording experiences, thoughts, impressions and ideas in order to reflect upon them and structure them into some sort of coherent representation is fundamental to constructivist learning theories. Participants frequently reported note taking as an informal learning activity in a variety of different learning contexts. In his analysis of how people write, Sharples (1999) describes a twofold writing strategy of 'knowledge telling' and 'knowledge transforming'. Knowledge telling involves a straightforward expression of ideas, each one linked to the next one. Knowledge transforming introduces an element of reflection to the writing process, requiring the organization of the stream of ideas into coherent concepts by combining and recombining them in the context of goals, beliefs and constraints. The creative note-taking activities described by participants consisted of both knowledge telling and knowledge transforming, and could be divided into two broad categories:

• Individual knowledge construction
• Collaborative/Distributed knowledge construction.

Individual knowledge construction
The individual knowledge construction activities ranged from knowledge telling (lists of topics to research, books to read and events to attend) to more reflective knowledge transformation (annotating downloaded material, making learning notes). Participants sometimes used the audio recorder built into the device to make notes:

> I use my voice recorder to record magic lectures. I also use the memo application for taking notes at magic lectures, taking down important information such as originators of magical effects, funny lines to remember, names of books, and various sleights to learn.

The advantages of using a mobile device (small size, portability, digital notes format that is easily shared with other devices) were mentioned by participants and appeared to outweigh any disadvantages of small screen size, slower data entry and reliance on battery.

Collaborative/distributed knowledge construction
Evidence of collaborative knowledge construction and knowledge transformation emerged as participants described their collaborative learning activities. Over a quarter (28%) described activities that they construed as collaborative informal learning. These generally

PDA/smartphone activity	Percentage of PDA/Smartphone users using organisational functions			Table 3. PDA and Smartphone organizational function usage.
	Cumulative daily + weekly	Daily	Weekly	
Calendar/contacts	93	84	9	
Tasks and other lists	79	60	19	
Spreadsheets or financial	46	20	26	
Password management	44	33	11	

occurred through the sharing of data in some way, either asynchronously by uploading onto a central server hosting a web forum, wiki or blog, or synchronously through messaging or face-to-face chats. Examples include:

> Collaborating photos and notes to a central server i.e. a wiki of sorts.
> Reading and posting on forums. Posting knowledge on blogs to share.
> My friends and I regularly discuss what software we have on our smartphones and regularly give each others tips when we find something new. forums are also a great resource for pooling collective knowledge and experiences.
> I use it to e-mail and/or chat with others when I have a question about something that I am doing, learning about or simply curious about and want an answer to at that moment and don't want to wait to use my PC.

Students engaged in formal learning activities described a time-saving approach to collaboration:

> Me and my friends tried to write down this year's English literature seminars' lectures – we've made a calendar so that each lecture would be attended by at least one of us. Typically, that person would record the 90 minutes of the show, then transcribe it as pure text, and upload it to a server we shared. I did my part of the job on my Palm.

Web forum users collaborated in many areas, helping each other solve technical problems by posting and answering questions in the forums and building collaborative data bases of information through wiki entries.

Adminstrative activities

PDAs have their origins as organizational devices and Smartphones have inherited this functionality, with 84% of survey participants using the Calendar/Contacts functionality on a daily basis. When asked what organizational features they used, PDA and Smartphone

responses were very similar, using the applications listed in Table 3 on a daily or weekly basis ($n = 154$):

These organizational uses were not directly related to the informal learning activities described by the participants. However, the high percentages of participants who use their mobile device to support their organizational needs may explain, in part, why many of them went to such lengths to use their devices to support their informal learning efforts. Their previous successful experiences with mobile technology may lead to more positive expectations, and their greater familiarity allows them to readily adapt it for use in other areas.

Results

The survey responses suggest that, for some mobile device enthusiasts at least, the answer to the first research question 'Do mobile device users use their mobile devices to support intentional informal learning?' is yes, they do. The data revealed that participants are prepared to adapt existing mobile device features to suit their learning needs, and may develop informal learning interests as a result of owning the device. The informal learning activities described by the participants made use of the unique affordances offered by the small-size and powerful computational capabilities of PDAs and Smartphones. Also striking was the ingenuity shown by participants in adapting and tailoring their mobile devices to their needs.

The second research question asked 'Do informal learners use mobile device connectivity to convert unforeseen events into informal learning occurrences, for example, by accessing situated content or contacting others with expert knowledge?' Again, the survey responses suggest that some informal learners do. Participants described occasions when they used their mobile devices to look up information related to an unplanned informal learning event, and it was evident

that Internet access, whether through wifi or GPRS, played an important role in supporting these unplanned informal learning activities. As mobile connectivity becomes more prevalent and less expensive, it is likely that informal learners will make increasing use of it to support such serendipitous learning. This has implications for formal educators which need to be explored in future work. Can we scope such learning 'opportunities' into our formal learning curriculums or would this disadvantage those with less access to mobile technology. If we provided connected technology, would this cause fragmentation and device conflict for those who preferred to use their own devices?

Research question three 'Does the mobile connectivity available with mobile devices such as PDAs and smartphones encourage or support collaborative informal learning?' is more complex to answer. In using and contributing to shared mobile resources, such as wikis, blogs or web forums, it could be argued that participants were engaging in *de facto* collaboration embedded in the structure of the activity and within the affordances of the tools used. However, other forms of collaborative learning emerged from the data. Eight participants mentioned GPS and two of these talked specifically about geocaching using their PDA or Smartphone. Geocaching is a leisure activity in which participants use a GPS mobile device to locate and log a caches hidden by others. The activity is coordinated via a central website through which geocachers communicate with each other and share details about physical locations and experiences. Geocaching is a social activity that builds and distributes knowledge across people and locations in a functionally collaborative structure that does not rely on connectivity between mobile devices. Instead, extended collaboration is supported by a range of synchronous and asynchronous technologies, including mobile devices. These emergent activities embody the extended interactions between people, artifacts and representations that characterize Rogers' definition of distributed cognition (Rogers 2006). They suggest that learners are adopting a holistic approach, integrating the functionality available through their mobile devices with Web 2.0 technologies to support their learning needs.

Conclusion

The enthusiasm the PDA and Smartphone users felt for their devices was apparent in the quantity and quality of the detail they provided about their informal learning activities. Although they were not immune to the usability problems cited by participants in other studies, they had overcome them and developed a level of confidence and competence that enabled them to realize the potential of their mobile devices beyond that of an electronic organizer.

In order to analyse the ways that participants used their devices in informal learning, a new analysis framework was developed; adapted from a framework used by Patten *et al.* (2006). While Patten's framework had worked well for analysis of mobile applications, it was not adequate for categorizing the *informal* mobile learning activities that were reported by participants in this study. The new framework classified the learning activities in six primary categories, and then qualified them with reference to five sub-categories. The activities were referential, location aware, reflective, data collection, constructive and administrative, and the qualifiers were individual, collaborative, situated, distributed and interactive. However, this framework is adaptable; as the range of features available with mobile devices increases, the mobile learning framework can be extended to accommodate new mobile learning activities.

All the categories identified in the framework were represented in the data; however, some appeared to be used more often than others. For example, there were many examples of learning activities that could be categorized as referential, reflective, constructive and administrative, and fewer examples of activities that could be described as location aware and data collection although some study participants adapted their mobile devices to simulate location awareness, for example, by downloading contextual information in advance of a planned visit.

A more authentic location aware activity might use location awareness built into the device (say GPS) to trigger content or action relevant to the context. However, the learning activities and interactions that the study participants engaged in were constrained by the mobile device functionality available at the time. At the time the survey was conducted, GPS devices were uncommon; nevertheless, some participants described location-aware leisure activities such as geocaching that could lead to informal learning events. Recent developments such as the release of devices, such as the GPS, GPRS and wifi-enabled HP IPAQ 6915, increase the

liklihood that location awareness will be used in support of informal learning activities. This has implications for location aware, situated learning in which learners engage with their geo-spatial context through their mobile devices. Mobile devices may be used both as a guide to specific locations, as a way of uniquely identifying locations as well as collecting and uploading data and linking it to a specific physical location.

Overall, the results suggest that mobile devices are used extensively in an informal learning context by enthusiasts, and that they use them in ways that correspond to the collaborative, contextual and constructivist mobile learning philosophies identified by Patten *et al.* (2006). The mobile device enthusiasts had already successfully adopted their devices and had integrated them into their daily lives. This integration meant that device users used their PDAs or Smartphones regularly, knew how to use them, always had them to hand and, when confronted with a mobile learning-related need, would naturally use them in preference to other tools. These findings suggest that as mobile technology developments advance, and as more functionality is built into compact handheld devices, device owners will use this functionality, along with a range of other technologies, to support both intentional and unintentional mobile informal learning.

Acknowledgements

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