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PDAs as lifelong learning tools: an activity theory based analysis

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This paper describes the use of an activity theory (AT) framework to analyze the ways that distance part time learners and mobile workers adapted and appropriated mobile devices for their activities and in turn how their use of these new tools changed the ways that they carried out their learning or their work. It is argued that there are two key strengths in using an activity theory framework in this context. The first strength is the emphasis activity theory places on tools, including computer artefacts, as mediators of activity. This emphasis focuses attention on the activity itself rather than, for example, simply the interaction between the human and the computer. The focus is on the learner or user's objectives and activities and the computer is the tool through which the user achieves her objectives. The second strength was referred to briefly above. The AT perspective also enabled analysis of an interactive dynamic process of users or learners and their tools—in this case personal digital assistants (PDAs). It revealed a two way process in which the user adapts the tools they use according to their everyday practice and preferences in order to carry out their activities; and how, in turn, the tools themselves also modify the activities that the user is engaged in. Three case studies illustrate these processes. The first case study is of distance learners' use of e-books on PDAs, to supplement their access to other static media such as books and computers. The second case study investigated how mobile workers in the energy industry used mobile devices to access information when away from the office. The third and final case study investigated the use of mobile devices in an art gallery. The paper concludes with a discussion of the information access needs that are apparent in each of these learning contexts, and highlights the pertinent issues in the use of mobile technologies to support lifelong learners' information needs.

Introduction

Recent technical developments in mobile devices, some of which now offer much of the functionality of a laptop PC, have converged with an increasing emphasis on life-long learning. The learners in question include those in learning institutions (e.g., schools and universities) and also workers and informal learners. Mobile devices have many features that could support these learners. Personal digital assistants (PDAs),

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for example, are portable and personal, and many enable users to access the Internet and communicate with other PDA users over a wireless network. These features give such devices the potential to support learners who are on the move or want to work in different locations. At the Open University we have a particular interest in supporting our part time learners, who need to fit their studies around many other commitments in order to make the best use of the time they have available. Many of our students are already working collaboratively with other students in our networked learning environment, and mobile devices offer the possibility for students to access and use course information and collaborate with others wherever they happen to be.

The paper begins with an overview of recent literature examining the use of mobile technologies as learning tools, followed by a discussion of the concept of lifelong learning. We then introduce concepts from activity theory that have informed our research into mobile learning and mobile work. One reason for our interest in applying activity theory concepts to evaluating technologies is its emphasis on technologies-in-use. As educational technologists we are only too well aware of the history of the adoption and lack of adoption and use of particular technologies which were thought to have considerable potential for education but turned out not to be so useful or revolutionary in practice. We therefore believe that it is particularly important to analyze how such technologies are used in practice and how they 'fit' or (do not) into a user's established ways of working. Activity theory allowed us to do exactly this. Our consideration of activity theory is followed by a discussion of the use of PDAs to support distance education, mobile knowledge work and learning in museums. This discussion will draw on data from recent case studies conducted by Waycott (see Waycott, 2004). The paper will conclude with a discussion of the information access needs that are apparent in each of these learning contexts, and highlight the pertinent issues in the use of mobile technologies to support lifelong learners' information needs.

PDAs as learning tools

There has been a vast increase over the last five years in the educational technology literature regarding the use of personal digital assistants (or PDAs) and other mobile technologies as learning tools. PDAs are palmtop computers, originally designed to support business workers' time and information management needs. However, their capabilities have since expanded and merged with other technologies such as mobile phones, extending the possibilities for providing users with information access anytime, anywhere. Some researchers believe that such tools have the potential to revolutionize learning, enabling learners to undertake various learning activities wherever they happen to be (Soloway *et al.*, 2001). Whether or not they revolutionize learning, there are clear potential benefits to learners in using mobile technologies. Mobile technologies are personal and portable; therefore they may incite in learners a feeling of personal ownership over learning tasks and the technologies used to support learning (see Hennessy, 2000, for example). Furthermore, the portability of PDAs and other handheld devices means they could potentially be used to facilitate

information access 'anytime, anywhere'. This is particularly true with the addition of wireless communication capabilities which enable users to access the Internet and communicate with other PDA users. Indeed, much of the recent literature that falls under the rubric of 'mobile learning' research has focused on the use of PDAs as collaborative learning tools in school settings, both inside and outside the classroom (see Hennessy, 2000; Curtis *et al.*, 2002; Davis, 2003; Zurita & Nussbaum, 2004).

There has also recently been much interest in the use of PDAs in higher education, particularly for accessing learning materials. For example, many US colleges and universities have taken part in the Palm Education Pioneers project, providing students with Palm PDAs that can be used, for example, to connect to campus networks, or to download and store essential information resources—such as legal students' case notes (PalmOne, 2004a, b). Closely related to this is the body of recent research exploring the use of e-books in learning and workplace settings (see Bellaver & Gillette, 2002; Kukulska-Hulme & Pollard, 2003). E-books can be broadly defined as any book-length documents (e.g., manuals, textbooks, novels) presented in digital format, whether they are read over the Internet, on desktop computers, on PDAs, or on dedicated e-book readers. Although some authors have begun to assess the use of e-book readers in educational and collaborative work contexts, e-book readers are yet to gain widespread market success. However, e-book reading software is widely available for use on PDAs. Therefore, examining the use of PDAs as tools for reading electronic text is a timely research concern. This is addressed below, particularly with reference to the use of PDAs by distance education students.

Lifelong learning

There has been and continues to be an increasing emphasis on lifelong learning over the last 10 years. This kind of learning, which often takes place outside formal courses, is very diverse—and could include, for example, learning to identify garden plants, to cook or to fill in tax forms—and there is evidence that such learning is a significant activity in people's lives. Vavoula and Sharples (2002), for example, as part of research in designing a system to support everyday learning, investigated learners' daily learning over a period of four days. They found that learning is mobile with respect to place, (taking place in the workplace, at home or in other locations); it is mobile between different areas of life (e.g., is related to work or to leisure or to self improvement) and is mobile with respect to time (happening at different times of day and at different points in the week). Their findings distinguished between learning *episodes* (single learning experiences) and *activities* (where such experiences are grouped together by theme and projects, involving purposes and outcomes). In carrying out these episodes, activities and projects, learners used a number of very different kinds of learning resources and reported a variety of ways of organizing their learning.

Lifelong learning is open to different interpretations and there are certainly debates about its definition. Indeed a recent European Commission briefing paper (2001) states that 'Lifelong learning is a rather nebulous and multifaceted concept' and adopts the following definition:

> Those novel forms of teaching and learning that equip students (learners, individuals) to encounter with competence and confidence, the full range of working, learning and life experiences. (p. 1)

According to this definition lifelong learning may, therefore, involve small episodes of activity that enable learners to complete certain tasks which may increase their workforce skills. Indeed much of the emphasis in a UK government Green Paper on lifelong learning, *The learning age* (DfEE, 1998), is on skills that are of use to the workforce. However, many activities are related to learners' personal lives rather than their work lives. Cook and Smith (2004) give the example of someone who wanted to learn to email in order to maintain contact with her grandchildren, who were living in a different country. Learning outside formal educational institutions can also include incidental learning—where learners have not set out with specific learning goals. Vass (2004), for example, discusses how the children she studied in classrooms brought with them skills they had learnt outside the classroom—at home and in the playground—and applied them successfully in collaborative projects in the classroom

The concept of mobile learning emphasizes the fact that learning is not confined to a location, such as the classroom, but is, essentially, a mobile activity that forms an inherent part of everyday life. Alan Kay, one of the earlier advocates of the use of portable computing technologies in education, argued that educational technologies should be mobile because children and learners are mobile (Kay & Goldberg, 1981). Indeed, many of the more traditional technologies used to support learning—such as pen and paper, calculators and books—are already portable. Kay was motivated to design the first handheld computer, the Dynabook, because he wanted to make computing technologies accessible for children and useful in an educational context: 'I realized that if you're making something for kids, you have to make it portable … [so] I started sketching the Dynabook' (Shreiner, 1998). Unfortunately, the development of the Dynabook did not proceed beyond the prototype phase, although it has since been replaced by other portable technologies such as laptop and handheld computers.

Building on Alan Kay's vision, Sharples (2000) likened mobile learning to the concept of lifelong learning, arguing that learning can take place at various points over a person's lifetime, and is not confined to the classrooms or lecture halls of formal educational institutions. Therefore, according to Sharples, the design of personal technologies to support lifelong learning should aim to facilitate 'anytime, anywhere' learning, and should encourage the participation in learning activities across a lifetime.

The use of PDAs as informal learning tools has perhaps received the most attention in the context of visiting museums and art galleries (Fleck *et al.*, 2002; Hsi, 2003; Proctor & Burton, 2003; Proctor & Tellis, 2003). In such contexts, the PDA is not really a personal tool. Rather than owning the PDA, the user borrows it from the museum for the duration of the visit. The PDA can then be used to access information relevant to the artefacts on display. For instance, in the Tate Modern gallery in London, PDAs are being used to deliver multimedia content that contextualizes the work on display, using a combination of video (e.g., images of the work being

created), audio (e.g., interviews with artists), communication facilities (e.g., the option to send text messages to other museum visitors), and interactive games (Proctor & Burton, 2003; Proctor & Tellis, 2003). This context formed the focus of one of our recent studies and will be discussed further below.

This brief review and discussion has highlighted that there are many potential benefits that PDAs could bring to a range of learning activities. However, new tools also, inevitably, introduce constraints (Carroll *et al.,* 1991; Wertsch, 1998). The constraints of PDAs are as equally apparent as their potential benefits. They have small screens, and therefore the amount of text or graphics that can be viewed at any one time is limited. They also have limited data input methods, usually involving a pen-like stylus on a touch-sensitive screen. Most handheld computers have hand-writing recognition systems to enable data entry. However, these are often perceived as slow and awkward to use (Sears & Arora, 2002). Such constraints have prompted some researchers to develop mobile devices that are specifically designed for learning (Sharples, 2000). However, although PDAs were not designed for educational purposes, learners will make use of whatever tools they have to hand, so we also need to investigate how learners use commercially available mobile devices such as PDAs.

Given the constraints that we have discussed, however, it is also important for educational technology research to focus not only on how new technologies enhance learning, but also to assess the potential negative impacts that new tools can have. The theoretical framework outlined below, which draws on key concepts from activity theory, provided a way of looking at how the PDA mediated (changed) learning activities in different settings by introducing both possibilities and constraints. These had both beneficial and negative effects on the learning activities, which will be discussed below.

Activity theory

Activity theory (AT) has evolved from decades of theorizing based Marxist philosophy and Soviet psychology and related traditions (Vygotsky, 1978; Leont'ev, 1979). As Kuutti (1996) attests, activity theory is not actually a theory as such, in that it is not 'a fixed body of accurately defined statements' (p. 25). Rather, it is a collection of broadly defined concepts that are open to interpretation. The description presented here, then, is our interpretation of the key concepts that have been particularly relevant to our research and helpful in providing an explanatory framework for the data.

We noted earlier that an important strength of activity theory in evaluating learners' use of mobile technologies is its notion that tool mediation is central to all human activities. This emphasis on tools, including computer artefacts, as mediators of activity focuses attention on the activity itself rather than simply the interaction between the human and the computer. In other words, the human is seen to be doing something other than using the computer: the computer is the tool through which the user achieves her objectives. Therefore, according to this perspective, evaluation of

computer artefacts should focus not only on identifying usability issues, but also on examining how well the tool supports the user's activities.

Activity systems

Activities involve communities of people and are embedded within particular social settings. This idea is typically illustrated by Engestrom's (1987) 'activity system' framework. This framework incorporates the *subject*, or person acting on the world, the *object* towards which the activity is directed (representing the activity's motive) and the *tools*, through which the activity is mediated. Engestrom added to this basic triangle three further components: the *community*, *rules/regulations* and *division of labour*, which each have a mediating role in the execution and development of the activity. There is some ambiguity in the activity theory literature about the distinction between the subject of the activity (or the actor) and the community. For the purposes of clarity, in this paper we will refer to the subject as an individual, while the community represents the collective part of the activity. Members of the community are involved in activities that are related, but not identical, to the central activity system. The rules or regulations in an activity system can consist of formal laws and procedures as well as more informal and implicit ways of doing things. The division of labour 'refers to both the horizontal division of tasks between the members of the community and to the vertical division of power and status' (Engestrom, 1993, p. 67). It is through the 'horizontal division of tasks' that actions, described below, are divided among members of the community.

Activities, actions and operations

Activities consist of specific goal-directed actions, which in turn constitute operations, the routine, automatic processes that enable the goal of the action to be reached (Leont'ev, 1979). Actions are achieved through the use of available tools, which represent the 'conditions' of the activity. The conditions of the activity determine the operations, or routine processes, that are used. Operations are not typically available
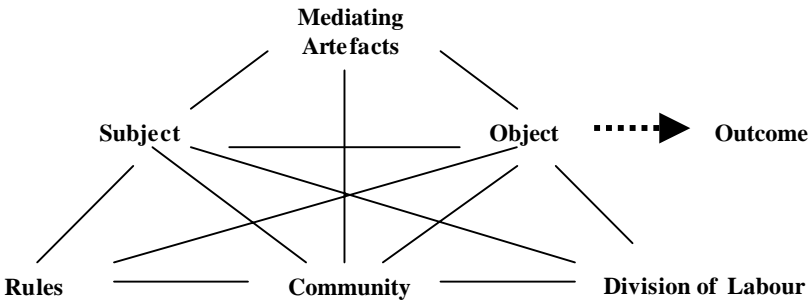

Figure 1.   Activity system triangle (adapted from Engestrom, 1987)

in conscious awareness (Nardi, 1996) so people do not normally have to think about those operations. One example would be changing gear in a car—which experienced drivers carry out without thinking about the process. When people do have to think about an operation, however, it ceases to be an operation, and instead moves to the level of an action. The distinction between activities, actions and operations can be illustrated by the example of the activity of reading course materials on an Open University course, which was the focus of the first case study in this research. Some of the actions contributing to this activity might include reading specific documents, taking notes discussing the course materials with other students, and so on. The operations would include turning pages in the document, using a pen and paper to take notes, and flicking through the document to move back and forth between sections. The operations are dependent on the conditions of the activity. For example, if a student was reading a document on the PDA rather than on paper, then the operation of 'flicking through the document' would no longer apply. Instead, the operation might be to scroll through the screen displays of the text.

Activity system development

Like all elements of an activity system, actions and operations are not static but change as the activity evolves. For instance, some actions may, over time, become routine processes that no longer require conscious awareness. Thus, they become 'operationalized'—that is, transformed into an operation. The often cited example that Leont'ev (1979) gave, referred to in the last section, is that of learning to drive, in which initially 'every operation—e.g., shifting gears—appears as an action' but over time gear-changing 'is no longer carried out as a special goal-directed process' but becomes an operation within other actions (p. 64). Conversely, operations can become actions when the conditions of an activity change. Bodker (1991) gave the example of using a new word processor when writing a letter. In this instance, the operations that had been built up through the use of more familiar tools would no longer apply, and the user would need to execute each process involved in writing the letter as a specific goal-directed action. This can be likened to any instance in which a new computer tool is used to support a work activity. Initially the new tool makes it impossible to utilize the individual's 'repertoire of operations' (Bodker, 1991, p. 27). However, as the new tool becomes familiar to the user, she may develop a new set of operations that relate specifically to the use of that tool. As more operations relating to that tool develop, use of the tool becomes easier and less prone to 'breakdowns', that is, situations in which there is conflict between the operations at the user's disposal and the operations required from the specific conditions of the activity (Bodker, 1991). Thus, a new tool can have a substantial impact upon the transformation of actions and operations.

Activities also evolve through the introduction and resolution of contradictions in activity systems. Contradictions 'manifest themselves as problems, ruptures, breakdowns, clashes' (Kuutti, 1996, p. 34). There are always contradictions in an activity system, and they are necessary, although disruptive, for the development of the

activity. The concept of contradictions is a useful analytical tool, enabling the iden-tification and classification of particular instances of change and development in an activity system. Analyses directed towards the identification of contradictions in an activity could enhance educational technology research in two ways. Firstly, such an analysis may give rise to opportunities for the development of new computer tools to support a particular activity system (see Turner & Turner, 2001). This relates to the initial phase in the task–artefact cycle by Carroll *et al.,* in which an artefact or tool is developed and put into practice in response to a particular need that arises within the tasks the user performs (Carroll *et al.*, 1991). Meanwhile, in line with the second phase of the cycle, the introduction of a new tool would also modify the activity system, thus resolving or creating new contradictions between the different components in the system. Engestrom (1993) suggested that when a 'novel' element is 'injected' into an activity system it creates new contradictions which lead to further development of the activity system. Thus, research examining the impact of a new technology in a particular learning or workplace setting should include consideration of the contradictions in the activity system—both those contradictions that the new tool helps to resolve and the contradictions created by its use.

These concepts were particularly helpful in considering and analyzing how differ-ent participants in our case studies used mobile devices across the different settings of learning, work and visiting an art gallery. These case studies are considered next.

Learners' information needs in three contexts

In order to illustrate the potential for mobile technologies to support lifelong learn-ing, in this section we outline three different contexts of learning in which learners' information needs could potentially be met by the appropriate use of portable tools such as PDAs. This discussion will draw on recent literature as well as the case stud-ies we have carried out (Waycott, 2004). These involved exploring the use of PDAs in (a) a distance education setting; (b) an international organization involving mobile knowledge workers; and (c) an art gallery.

Case study 1: distance education

In this section, we will summarize the findings from a case study that examined the use of PDAs as tools for reading course materials by distance education students (see Waycott, 2002; Waycott & Kukulska-Hulme, 2003). The purpose of this study was to examine the effect the PDA had upon the activity of reading in this context, as well as to determine how useful the PDA was as a learning tool. Sixty-five postgraduate students on an Open University masters course were supplied with a Palm m105 PDA, along with software for reading the course texts. Three sections of the course 'Study guide'—a collection of discursive texts written by academics associated with the course—were made available to download onto the PDA, although students also had access to the printed version of the 'Study guide', provided on A4 loose paper

collected together in a ring-bound folder. Therefore, use of the PDA, and participation in the study, was voluntary.

Pre- and post-questionnaires were administered online, with 44 and 35 responses received, respectively. Students also took part in an online discussion, where they exchanged their views about the PDAs; contributions to this constituted further data for the case study. In addition, 10 students were selected from the entire cohort of students to take part in a telephone interview at the end of the course. These interviews provided in-depth data about how students had used the PDAs and how the new tools had changed the reading activity.

Students varied greatly in the way they responded to, and used, the PDA. Of the 35 students who responded to the post-questionnaire, only 10 said they used the PDA more than once a week to read the course materials. Only five students found the PDA *very useful* as a reading tool, while quite a large proportion—15 students (43%)—found it *somewhat useful*. Meanwhile, over 20 respondents said they found it *somewhat* or *very difficult* to read course materials on the PDA. Thus, it appears that while many students found the PDA useful (or at least somewhat useful) as a tool for reading course materials, many students also felt the PDA was quite difficult to use for this purpose.

These findings are difficult to interpret without reference to the interviews, which provided a much richer understanding of how and why people differed in the way they used and responded to the PDAs. For instance, one interviewee, Jane, was particularly enthusiastic about the PDA; she already owned another handheld computer, which she used extensively as a personal time and information management tool. However, when taking part in this study she found the PDA difficult to use as a reading tool as it caused eyestrain, resulting in headaches and blurred vision. Nevertheless, Jane's evaluation of the potential for the PDA to support her learning activities was overwhelmingly positive. For Jane, the portability of the PDA was a key benefit, enabling her to fit the reading activity around the many other activities in which she was involved:

> It was so much easier to do the work, you could do it everywhere and when you're trying to fit it in around work and kids and everything, that was an enormous advantage.

Another student found the PDA enabled her to 'fit studying into the gaps in between other things. Whereas with the computer I had to plan to be near the computer'. Fitting study 'into the gaps' was important for students on this course. A general characteristic of Open University study is that it is flexible: it is typically undertaken part time and students must fit their studies around other activities such as work and family commitments (Jones *et al.*, 1993). It was, therefore, an unwritten rule that, in the words of one interviewee, 'you use every little spare bit of time you can' in order to successfully complete the course. Existing tools, such as the bulky A4 course folder and desktop computers, were not conducive to this rule. In other words, for some students there was a contradiction within the activity system of their OU studies between the rule and existing tools. The PDA helped to overcome this contradiction, providing a means of accessing sections of the course

materials wherever, and whenever, there happened to be a spare window for their OU studies.

However, this positive outcome must be countered by recognition of the negative experiences that students also encountered. As outlined above, many students found the PDA difficult to use as a reading tool. These difficulties included the fact that familiar navigational clues—such as page numbers and document weight—were missing, students felt they could not gain an overview of the contents of the text, and it was difficult to skim-read through the text. Thus the characteristics of the device that made the PDA valuable in this learning setting—its small size—also made it difficult to use as a reading tool. This meant that processes that would have been routine operations when using paper—such as flicking back and forth within a document—became time-intensive actions.

This was also the case when the PDA was used for taking notes. Some of the note-taking and highlighting strategies that students said they used when reading from paper were not supported on the PDA. For instance, it was not possible to write notes in the margins or scribble diagrammatic notes on the text. Instead, note-taking while reading on the PDA involved either writing the notes within the 'Study guide' document, or opening a separate file and recording the notes there. This then involved an awkward process of moving between the main document and the notes file. Furthermore, some students found the handwriting recognition system on the PDA difficult to use, involving new time-intensive actions, rather than the familiar operations they would have used when writing with pen and paper.

Thus, the PDA both introduced and resolved contradictions in the activity system of reading course materials on an OU course. The PDA clearly supported OU students' information access needs, particularly for those students, such as Jane, who had to fit studying into the short breaks that occurred within other activities. It appears, then, that part time distance education students have a clear need for portable technologies that provide 'anytime, anywhere' access to learning materials. However, they are by no means unique in this respect. There are many other examples of higher education settings where students travel frequently or undertake practical activities that leave only short periods of time in which they can undertake their self-study activities. For instance, the use of PDAs to store essential information resources has become particularly prominent in the context of medical education and practice (Smordal & Gregory, 2003). A study in Norway investigated medical students' use of PDAs as they underwent practical training at hospitals and general practitioner (GP) surgeries (Lundby, 2002). They were provided with an 'e-book' version of their main reference text and could also use wireless communication to access email, the Internet and the networks in hospital and GP surgeries. The intention was to provide students with 'just-in-time' access to information resources, so that they had all the information they required, when and where it was needed (for example, while assessing a patient or while writing up case notes about their practical work experience). However, the study revealed that students rarely used the PDA. In fact, some students did not carry the PDA with them at all, preferring instead to use other resources such as paper artefacts, desktop computers, or to consult experienced

practitioners for advice (Kasbo *et al.*, 2002). Some of the complaints about the PDA included the constraints that we are aware of from our own case study and the literature: the small size, limited battery life and awkward means of entering text. They also referred to an unstable network connection, due, partly, to the use of prototype technologies that were prone to breakdowns. One student explained his preference for the paper textbook rather than the e-book version:

> Tables and figures were distorted, and due to the screen size the pages were small and numerous. This made navigation complicated. It is hard to compete with the neatly organised index of a traditional handbook in any case. (Hov, 2002, p. 16)

This is a common finding in research that has compared the use of electronic text with paper documents. Users familiar with paper documents can 'flick' back and forth within the document and remember the location of important material. In contrast, electronic text contains different contextual clues and is not physically malleable like paper. Therefore, it is more difficult to navigate (Dillon, 1994; O'Hara & Sellen, 1997). This was certainly one of the findings that arose from our study of OU students' use of PDAs as reading tools.

Case study 2: mobile knowledge workers

Like mobile learning, the concept of mobile work has received much attention in recent years, along with the similar notion of mobile computing. Indeed, mobile computing is often referred to as 'access anytime, anywhere', a phrase that has been closely associated with the ideals of both mobile learning and mobile work (Perry *et al.*, 2001). In this paper we have used the term 'mobile knowledge workers' to describe people who travel frequently for work purposes, and whose work revolves around the creation and use of information resources. These are people who, while out of the office, need to have constant access to up-to-date information. Like the distance education students described above, they have particular needs for information access that could be met by the appropriate use of portable technologies such as PDAs. The following describes a case study in which we examined the use of PDAs in a large international organization, known here as NatGasCorp (NGC).

Sixteen staff members were interviewed for this study. Interviewees derived from several departments and teams across the organization. The interviewees included a petrophysicist, responsible for assessing and analyzing the resources found at gas and oil exploration sites, risk analysis officers, who assess the risks involved with the various international business assets managed by NGC, and public relations officers, who ensure that all NGC's communications with the press and international governments present the organization in a positive way, so as to maintain shareholder value.

Many of the interviewees were required to travel internationally for work purposes, typically for a week or fortnight at a time, several times a year. Along with the emphasis upon mobile working, there was a strong emphasis upon knowledge sharing and skill development within the organization. A common theme that emerged from the interviews was the importance of communication among colleagues and the necessity

of tools that supported the constant sharing of information. It was this need which motivated the initial introduction of PDAs into the organization. Palm PDAs were supplied to managers in 1999. Although the PDAs did not have wireless connectivity, and therefore could not be used as communication tools, they did have a facility for downloading data from the company Intranet site. The NGC Intranet was known as KITE (*Knowledge and information to everyone*), and was made available on the PDAs through AvantGo software (an application used to truncate and download selected web sites onto the PDA). The purpose of KITE was to provide a facility for storing company information, such as press releases, company policies, and staff details. It was hoped that having that information available on PDAs would make it more accessible for staff who frequently worked away from the head office.

However, at the time of the study, the PDAs were no longer being used for this purpose. Some of the staff still used PDAs, but very few people used them to download the company Intranet, and most used them simply as electronic diaries and address books. The company's IT team was concerned about whether this was an efficient use of the PDAs.[1]

It appeared that several factors had contributed to this outcome. The staff member responsible for initially introducing PDAs and AvantGo software to the organization left the company following a demerger in October 2000; therefore the project was not maintained. Furthermore, the use of the KITE system in general was disappointing. It was used as a repository of information that dated very quickly; therefore staff found it an unreliable tool for accessing current information. At the time of this study, the KITE Intranet was being replaced with a new Intranet portal that, it was hoped, would provide more up to date information and would be better designed to meet individual staff needs through personalization of the tool. It was intended that the new Intranet would initially be made available to staff working in the head office and, over time, could also be used by other offices throughout the world and eventually by mobile workers through laptop computers or PDAs. Meanwhile, it was also intended that the Palm PDAs be replaced with new, higher-specification devices. It was hoped that these new devices would provide users with a more effective mobile working tool that enabled the use of a range of powerful functions.

During the interviews, it became clear that there was a contradiction between members of the NGC community regarding mobile workers' information access needs. The technology providers were clearly concerned with providing tools that facilitated employees' *access* to essential information. However, many interviewees used technologies while away from the office to *produce*, as well as access, information. There appeared to be two types of mobile workers at this organization, described by one interviewee as a distinction between 'passive' and 'active' mobile working:

> I think passive is where you're out, you're at meetings, you're in front of clients, you need to access your data, and that [PDA] should be fine. … I'm an active mobile worker in that I go away to do a week's work, I just don't happen to turn up here to do it, I go to Brazil. So I need full office functionality while I'm away … I need the full system, I need to sit down and be able to create PowerPoint presentations …write long word documents, have full email functionality and have equipment.

Many of the interviewees in this study were active mobile workers. While working remotely, their tasks would include collecting and analyzing data, interviewing people, attending meetings, writing notes and producing reports, preparing and giving presentations. Whilst carrying out these tasks they maintained contact with the office and other colleagues through email and mobile phones. For these workers, the laptop computer was an indispensable mobile working tool. They always carried their laptops, and so they felt they had little need for a PDA as well:

> I was using the Palm to do things that I would rather have a laptop for. And since the laptop and the Palm and the mobile phone usually ended up in the same briefcase, I ditched the one that was least useful.

That is, there was conflict between the tools used to support mobile working activities.

However, some interviewees felt the PDA could be used effectively in conjunction with the laptop. For some, the PDA could be used as an alternative to the laptop when the laptop was not required. For example, the Risk Analysis Director would take his PDA and not the laptop if he was only going away for a few days and doing 'lightweight' work, such as attending meetings. Furthermore, he preferred to leave the laptop at home when traveling to countries where theft and personal security were major concerns. In this situation, the PDA would provide him with access to small amounts of essential information, making it possible to travel without the laptop. In other words, the PDA helped overcome a contradiction between the tools used (laptop) and one of the rules of mobile working (maintaining personal safety). However, this was only possible because of the division of labour; the Risk Analysis Director tended to do lightweight (passive) work while away, whereas his colleagues did heavyweight (active) work that required the use of a laptop.

Some interviewees also described contradictions within their work activities that could have been resolved with the use of particular software on the PDAs. For instance, communicating information about NGC—to the media, to shareholders, and within the organization itself—was an important activity, governed by a multitude of rules and regulations, and reliant upon the use of many information resources including Internet sites, trade publications, libraries of relevant information, and press cuttings. According to the rules of the activity, it was important for Public Relations staff to have constant access to these information resources. Public Relations team members were expected to be available as 24-hour press contacts. It was therefore important that PR officers always had all the necessary information resources to deal with press enquiries readily available. Both the Public Relations interviewees spoke of the potential benefits of being able to send and receive information from a mobile device, particularly with regards to fitting the work activity around personal activities:

> The nature of … the media world is seven days a week, so at weekends I need to have access to information and potentially to contact people, to answer emails or … say to a journalist 'I will email you this information' or whatever. At the moment I can do that on a laptop. It would be much easier to do it on a smaller device. I'm not always at home, either, and I don't really want to travel with my laptop everywhere I go. It's also evenings.

> It's not rare that I'll be out having dinner with friends and I'll have to deal with some issue. If I can actually send information and receive information that would be very useful.

These comments suggest that there was a contradiction between the tools available and the rules of the activity. That is, the tools used (for example, a laptop computer and briefcase full of information) did not adequately fit in with the rule of being available around the clock as a press contact. While those tools were considered sufficient when the employee was situated at home or in the office, they were inconvenient at other times, for example social occasions such as going to the cinema or going out to dinner. In this activity, then, there was a clear potential use of PDAs or other mobile devices as tools for accessing and communicating information.

Similarly, one of the interviewees—whose job title was Science Director—had responsibility for dealing with any operational incidents that occurred and therefore had to have constant access to information detailing the rules and procedures to follow if such an incident did occur. This information was provided in paper form, in a small book. However, much of the information within it—such as telephone numbers—went out of date very quickly. There was, therefore, a contradiction in the activity system: the primary tool (a paper handbook) did not adequately support the rule that the person responsible for operational incidents (the Duty Manager) must have all the necessary information at his 'fingertips'. Furthermore, the printed handbook was considered 'awkward' to carry around, and when the Duty Manager was on duty, he or she had to have the handbook nearby at all times. Consequently, the Science Director said he would like to see the handbook made available electronically so that it could be kept up to date and so that it could be downloaded onto the Duty Managers' PDAs. Such a resource could potentially be updated automatically and whenever new information is entered into the handbook it could be downloaded onto the user's PDA. The PDA, then, could become a valuable tool for storing the Duty Manager handbook, resolving a contradiction in this activity system.

Both of the activities reviewed here reveal a need for NGC workers to have access to up-to-date information while they are away from the office. However, none of the required information resources were available for download onto the PDAs at the time of this study. Some efforts were being made to make this possible, particularly by the interviewees who were keen to see such resources added to the PDAs. However, when interviewees were contacted a year later about these applications, none had yet been made available for access on PDAs.

Case study 3: museum and art gallery learning

The activity of visiting a museum or art gallery is said to be a free-choice learning activity, which, according to Falk and Dierking (2000), 'tends to be nonlinear, is personally motivated, and involves considerable choice on the part of the learner as to what to learn, as well as where and when to participate in learning' (p. 13).

Museums and galleries have been identified as:

an ideal context for this 'free choice learning' wherein visitors absorb ideas and connections at random, based on personal interests and triggered lines of inquiry. (Proctor & Tellis, 2003)

However, some museum visitors might take part in a more structured educational program, for example a school field trip. In any case, the activity of visiting a museum or gallery presents many opportunities for learning.

Learning in a museum typically involves interaction with other members of the community in which this activity takes place. For instance, people may discuss with each other their reactions to the exhibits, school groups might be set assignments to complete during the visit, and many visitors are likely to make use of information provided by the museum curators so as to enhance their understanding of the works on display. Fleck *et al.* (2002) undertook a small study of visitor behaviour at the Exploratorium—a science learning museum in San Francisco—and found that social interaction was an important part of the museum experience. (However, we should note that the Exploratorium differs from other museums and galleries in that it is designed to foster social interaction.) Fleck *et al.* also noted that reading the information panels beside the exhibits appeared to detract attention from the exhibits themselves, but that visitors did seem to want to remember what they learnt in the museum, sometimes recording marginal notes in paper guidebooks.

Museum learning activities are often facilitated through the use of available technologies. Like many museums, the Tate Modern art gallery in London offers visitors the chance to use audio players with headphones to learn more about the artwork on display. The use of audio tours in museums and galleries has become common practice in recent years, particularly since digital audio technology became available. This means the audio content is no longer confined to what can be recorded on a cassette tape, which users would have to listen to in a pre-defined order. Rather, with digital technology, a larger amount of content can be recorded, and users can choose the order and length of their audio tours (Proctor & Tellis, 2003).

A natural progression from this format is to make use of handheld computers to provide visitors with multimedia content, such as text, videos, music and dialogue. This is what was intended by the first trials of PDAs at the Tate Modern, in 2002:

> … the Multimedia Tour allowed background information about the works on display to be provided to visitors in a variety of different media on a portable screen-based device. Visitors could see video and still images that gave additional context for the works on display, and could listen to an expert talk about details of a work, while the details were simultaneously highlighted on their screen. Interactive screens encouraged visitors to respond to the art on view, for instance by answering questions or by layering a collection of sound clips to create their own soundtrack for a work. (Proctor & Burton, 2003, p. 53)

The use of PDAs as multimedia tour guides in the Tate Modern first took place during a trial from July to September 2002. Tate Modern staff conducted a comprehensive evaluation of this trial, eliciting responses from 852 visitors who took part in the pilot, as well as gaining information from more in-depth focus groups. Lessons learned from this trial were then put into practice in the second pilot, which took

place in the latter half of 2003. It was during this trial that Waycott visited the Tate Modern to conduct the observation study summarized below.

The intention of the organizers of the PDA trials, at this stage of the project, was to 'focus on the interactive potential of the devices', including functions such as peer-to-peer communication and the facility for visitors to communicate with the gallery and send information to their home email accounts (Proctor & Burton, 2003, p. 55). It was also intended that during this trial the multimedia tour would expand on the content and facilities that proved to be particularly popular in the first pilot study, that is, 'to pinpoint the most successful methods and refine them to create specifically tailored multimedia learning models for visitors' (ibid.). This trial, then, provided a rich context in which PDAs were being used as learning tools, thus contributing an interesting illustration of the potential for PDAs as informal learning tools.

The observation study we carried out involved a one-day visit to the Tate Modern gallery in December 2003, in which the first author took part in the trial while also observing a volunteer who took part in the tour at the same time. Informal interviews were also carried out with four other visitors to the gallery, to gauge their impressions of the use of PDAs as learning tools in this setting.

The PDA tour provided information about 19 selected works on display in the 'Landscape/matter/environment' exhibition. Multimedia content delivered on the PDA provided information about the works on display in a variety of formats, such as through the use of audio dialogue, music, video, and still images. These were used to 'contextualize' the paintings—that is, to provide further information about the environment in which the work was created. For instance, when viewing Monet's 'Water lilies' painting, the gallery visitor could also access a photograph of Monet's garden, which was the inspiration for the painting, on the PDA screen. Similarly, visitors had the option to view video footage of Jackson Pollock creating one of his paintings, and they could also listen to music associated with particular pieces of work. This provided the visitor with further insight into the context of the painting, creating a link between the artist's world and the painting the artist had created.

The PDA tour included a small number of games and opinion polls, whereby visitors were invited to respond to a question or take part in a short activity. Although this appeared to be a valuable use of the PDA, technical difficulties meant that visitors could not make full use of these features. Similarly, technical difficulties were encountered when using the peer-to-peer communication facilities. The PDA tour included options for visitors to send text messages to one another. While this was an interesting use of the PDA, it was also rather limited. One interviewee described it as 'a little puzzling and limiting'. It was limiting because users were not able to create their own messages, but had to choose from the options available. That is, pre-written messages were shown on the screen and the user had to select which message she wanted to send. However, these messages represented the type of communication that might be considered peripheral to the main activity of learning about the artwork on display. For instance, they included items such as 'I am hungry' or 'I am tired'. It was not apparent, in this study, whether such messages would be useful to visitors or enhance the learning activity in any way.

Another facility on the PDA gave users the option to 'bookmark' sections of the tour. Information pertaining to the selected works would then be sent to the user's email address. However, this option did not appear to work. Although the researcher bookmarked some items and did later receive an email, the email did not actually contain any of the information selected. Furthermore, this facility did not offer users much flexibility regarding the information that could be sent home. For instance, users could not capture their thoughts and reactions to the works on display. Such a facility might have eradicated the need to take notes using pen and paper—which many visitors were observed doing. Using the PDA while also taking notes on paper proved to be problematic. Although the PDAs were apparently wearable—with the addition of the neck-strap—users still needed to hold the PDA at an angle in order to view the screen. The device, therefore, remained a handheld tool. Waycott (2004) described how she struggled to keep hold of her notebook, pencil, PDA and stylus, and during a clumsy attempt to switch between the pencil/notebook and the PDA, lost the stylus, which disappeared through a floor grate!

This point is relevant because many of the visitors (not using PDAs) were observed taking notes using pen and paper, including students in school groups and individual visitors. This raises a question about how PDAs might be easily used alongside other handheld artefacts when the user is truly mobile (for instance, walking around a museum).

One way that this could be overcome is to enable users to take their own notes on the PDA, and then send those notes home. However, it is important that the interface is kept simple so that it does not detract too much from the learning activity, particularly since visitors are only likely to use the PDAs for a relatively short period. This context of use was quite different from that explored in the previous case studies, where users had personal ownership over the device and had the opportunity to become familiar with the interface over much longer periods of time. As discussed above, data input methods on PDAs can be slow and difficult to use, particularly for new users. Therefore, this solution presents a contradiction: how to enable users to input text on the PDA while also retaining a simplistic interface.

This problem was also encountered by Fleck *et al.* (2002) in their study of handheld tools in the Exploratorium museum in San Francisco. They found that offering too many functions on the PDA was confusing for users and detracted attention from the museum experience, so they chose to focus on one function—providing a 'remembering' tool so that users could record information about particular exhibits to refer to at a later time. They provided visitors with a tag that could be swiped against the exhibit, so the corresponding URL for that exhibit would be stored and added to the user's visit record, which would be given to the user at the end of the visit. Initial studies showed that visitors liked this facility and that they found it easy to swipe the tags to record information. There was 'no indication that this disturbed their engagement with the exhibit or their companions' (p. 20). Most of the people studied did choose to look at the URLs after their visit to the museum, and several 'saved comments with their pages' (p. 20). Therefore, it was possible for visitors to record individual comments, but only when viewing the web site after their visit to

the museum. Thus, the problem of enabling visitors to record their own notes while also using a handheld tool such as a PDA was not resolved. This is a relevant issue for future research.

The PDA introduced many possibilities and constraints to the activity of learning in the Tate Modern art gallery. 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 in which museum visitors engaged. 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. The results of this study suggest that further research is warranted to ascertain the strategies learners use when visiting museums, and to determine how new technologies such as PDAs can best support those strategies.

Discussion

The first two case studies have two important features in common, although the contexts are very different. Firstly, the PDAs were personal devices that were owned by the participants. Secondly, although the learners were mobile in that they used their PDAs in different places, most of the time when the devices were used, the learners were stationary—sitting at a desk, on a train or at an airport, for example.

In both case studies, participants varied greatly in the way they responded to and used the PDA, as we have seen. Some found the PDA too small and text input methods—e.g., handwriting recognition—difficult to use. So they chose not to continue using the PDA and reverted to using other technologies. Some people persevered, however, and found ways of overcoming the usability constraints of the PDA—for instance, they used it in conjunction with a foldout keyboard or as an adjunct to the desktop computer so that entering text was not so difficult.

Some students in the first case study found the PDA really useful for providing portable access to their learning materials; others found the screen size to small to read from and they preferred interacting with text on paper. In the second case study, staff tended not to use PDAs to access the company intranet—but many did use them as organizational tools, and some had stopped using them altogether, preferring instead to use laptop computers or paper tools.

The personal nature of the PDA is important in considering the different ways that the participants used the PDAs and the differing motivations and investment that they were prepared to make: some participants were prepared to overcome challenges and adapt to using the PDA but others were not prepared to invest much time. However, in each case they were viewed as personal tools. This meant that where participants were prepared to invest effort in learning how to best use them for their own purpose, they could benefit from this investment as they were using the PDAs over a long period of time.

Using activity systems to interpret findings

The following discussion uses some of the concepts from Engestrom's extended activity system triangle to highlight the factors that influenced how and why participants used and responded to the PDAs in such diverse ways. This discussion will first of all briefly focus on two particular concepts: the subject and the mediating artefacts, or tools used in the activities (including both the PDA and other existing tools which participants used to support their activities).

The subject.   Turning first to the *subject,* each participant brought to the activity their own unique combination of past experience with other technologies, personal preferences for different work and study practices, and the time and motivation to learn to use the PDA and integrate it into their activities. In terms of past experience with other technologies, the most obvious example is that those who were touch-typists or who had a lot of experience using computer keyboards tended to dislike the handwriting recognition system on the PDA. Meanwhile, those who didn't like typing actually preferred having the option to enter text by writing on the screen rather than having to use a keyboard. People had also established their own preferred ways of working: sometimes the PDA matched these preferences and sometimes it didn't. For example, some students (case study A) found that the PDA did not allow them to interact with the text in the way they normally would—they couldn't highlight in colour, for instance, or draw diagrammatic notes on the text with arrows linking bits of text.

The tool.   Turning next to the *tools*: in some instances the PDA complemented other tools, e.g., it was used in conjunction with the desktop computer in both of the first two case studies and seen to extend its capabilities. Another example from case study A—where the PDA was used to read course materials—was that the PDA was not seen as replacing paper but was used in addition to the printed documents. However, many people who relied on a laptop computer, especially in case study B, felt the PDA conflicted with the laptop, rather than complemented it. This was because both tools were portable and therefore always available, and they were used to support similar functions.

So clearly the PDA did not replace other technologies but was used alongside them. It is important, therefore, for mobile technologies such as these to be designed to fit in with a suite of existing tools, allowing for seamless interaction between the different tools that people use. In case study C, however, this aspect was rather problematic. As we saw, the PDAs used did not allow for seamless interaction between the different tools—the PDA required too much attention and was too large to be used comfortably with a notebook for example. Furthermore, the PDAs used could not accommodate the activity that the additional tool was used for: they did not allow museum visitors to take the kind of personal notes that they needed. As we noted above, this problem was not resolved in either of the museum contexts and remains an issue for future research.

Mobile use with a loaned device

The third case study operated in a very different context: that of the museum or art gallery. Arguably, museums and art galleries themselves differ in many ways—but such a discussion is beyond the scope of this paper. In the art gallery context explored in our case study, there were two main differences from the first two case studies: firstly that the participants were using the devices whilst they were walking around. Thus, the devices are being used under different and more constraining conditions. Secondly, the devices did not belong to the visitors, but were on loan for the duration of the visit. This means that they were not personal devices in the same way as in the other two case studies, which could affect the participants' investment in learning to use the device. In this context, for it to be useful and usable, the device's interface must be close to transparent: for 50 minutes or so of use, there simply isn't time for the visitor to 'learn' to use the device.

Another factor in the art gallery or museum context is that the use of the handheld is more exploratory: the possibilities that it can offer are unknown. Whilst some of the advantages for the learner and mobile worker are also unknown, in case studies A and B the PDA was introduced to help solve a known problem: to enable the user to access (and produce) information using a portable device in different locations. In the context of the Tate Modern art gallery the PDA was seen to introduce many possibilities and constraints to the activity of learning and browsing in the gallery. The main possibility—the use of multimedia content—appeared to enhance the activity, and supplemented the information available to visitors whilst at the same time, supplying that information 'in context'. This, then, was a successful use of the PDA. The text messaging option, by contrast, was not. It neither successfully emulated the spontaneous verbal communication in which museum visitors engaged, nor did it introduce a different positive activity.

Some of the technical difficulties, such as battery life, are true across all three case studies. However, they appear to cause more difficulties in the more challenging environment of the art gallery. Here there is also the addition of the novel interface, and awkward means of carrying the tool. These factors constrained the activity, causing temporary breakdowns and shifts in focus from the activity to the tool itself. The need to hold the PDA in the hand, along with the accompanying stylus, made it difficult to also take notes on paper, yet note-taking is an activity that some visitors want to undertake; especially those who are visiting the gallery for learning purposes.

Summary and conclusion

This paper has reported on the use of PDAs in three contexts that could each be considered examples of lifelong learning settings: distance learning; mobile working and visiting an art gallery. Like other mobile devices, PDAs have not been designed with learners in mind, yet they offer great potential to support lifelong learning and indeed are being extensively used by learners. Therefore it is important to investigate how learners make use of such devices: what benefits the devices enable and what

problems learners encounter. The participants' use of PDAs in these different case studies has been analyzed through the lens of an activity theory framework, which provided a way of looking at how the PDA mediated learning activities in different settings by introducing both possibilities and constraints.

The three case studies differed significantly in the extent to which the learners were mobile whilst they were carrying out their activities—as in the art gallery where they were walking around, and how personal the devices were. Other research (see Hennessy, 2000) has shown that where learners have devices for extended periods, they develop a strong sense of ownership over both devices and the tasks for which they use them. In the gallery and museum, the devices were loaned out for short periods—and this means that this sense of ownership cannot be capitalized on and in addition, there is no time to 'learn' to use the device: it must be transparent. By contrast, in the first two cases, although all participants recognized the constraints of the PDAs, whilst some chose not to use them and sometimes reverted to other tools and technologies, others persisted and learnt ways of using the PDAs that they found beneficial; that supported their learning or information needs and meant that they could use the time they had flexibly.

The AT framework enabled us to focus the analysis on the extent to which the PDAs supported or constrained the user's activities—and allowed us to investigate how this played out for different participants as we have summarized above. Focusing on the level of the activity also meant taking into account how using the PDA fitted—or not—with other tools that were used for the activity. In addition to the tools it also allowed us to focus on the participants themselves—e.g., their personal histories and contexts—as discussed above.

The first two case studies suggest that the use of mobile devices such as PDAs can support lifelong learning—but as yet, the devices that are available commercially are still not ideal, and bring with them constraints as well as benefits. For some people, these constraints will outweigh the benefits. Using PDAs as truly mobile devices in contexts where learners are walking around is even more challenging. However, for certain areas of learning—for example some kinds of informal learning in science—the potential benefits are particularly striking. Using mobile devices for bird watching, for example, (see Chen *et al.*, 2003) not only allows the kinds of benefits we have seen here, e.g., of using small patches of available time for learning, but would also allow learners in different areas to collect information from different sites and compare it and discuss it. This is the area in which we intend to carry out further work.

Notes

1. As discussed in a meeting with NGC IT staff, 21 May 2002.

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