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Mobile and PDA technologies and their future use in education

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Introduction

In recent years there has been a phenomenal growth in the number and technical sophistication of what can loosely be termed ‘mobile devices’. In using this term we encompass both the ubiquitous mobile (or cellular) phone and also a range of information processing devices ranging from Personal Digital Assistants (PDAs) to more media-orientated gadgets that play video and MP3 music files. All these devices share the key characteristic of mobility and, to varying degrees, they can process digital data and digital media. Moreover, ever greater numbers of these devices are becoming Internet-enabled. Increasingly, staff and students within higher education institutions own and make use of these devices, particularly, in the case of students, in the main target age group of 18 to 24 years. Currently this use is often personal, informal and *ad hoc*, but increasingly universities and colleges will need to respond technically, pedagogically and socially to the large numbers of staff and students familiar with such devices and keen to incorporate them into the process and administration of research and education.

In order to assist with the process, this JISC TechWatch report aims to review the current technical situation with regard to mobile devices and then begin to map out the future directions these devices might take. Although much research has been conducted within schools on the use of PDAs to enhance education, it is more likely that future versions of smartphones (a hybrid of PDA and phone technologies) will form the basic technical platform. We review these issues from a primarily technical viewpoint, but also with respect to the educational and social issues that are raised. Despite the obvious pressure to make more use of devices that most students will possess there is little point in investing resources to develop infrastructure and support services unless there are strong educational or administrative reasons to do so.

Technically, we are entering a period of very rapid change for these devices as smaller, faster hardware technologies coincide with developments in the delivery of Internet access through wireless networks and 3G cellular phone networks. In such an environment, predicting long-term trends and changes is problematic. However, we do expect to see an increasing amount of convergence between types of devices, particularly with the introduction of very small hard disc drives and new battery technologies. Some analysts expect to see complete convergence between all mobile devices; others see a role for simpler, specialist information appliances that focus on particular tasks. Either way, their ability to use the Internet will open new avenues for collaborative learning and working on the move.

Definitions of mobile devices

In his recent article on mobile devices, Alan Livingston (2004) defines them as being 'small enough to fit comfortably into a purse, pocket or holster, so you can conveniently keep it with you at all times.' In the UK we would probably equate this to saying that mobile devices are small enough to fit into a pocket or shoulder bag so they can be kept with us at all times.

Within the parameters of this definition there are currently three major classes of product: Personal Digital Assistants (PDAs), mobile (or cellular) phones, and Personal Media Players (PMPs).[1] We do not consider tablet and laptop PCs within this report. This is in part because they do not fit within Livingston's definition, and, in accordance with the IEEE's (2002) distinction between portable and mobile, would be classed as portable.

The term "personal digital assistant" is generally viewed to have been coined by Apple CEO, John Sculley in January 1992 during the product introduction of the Apple MessagePad (which later became known as the Newton). This product is regarded as the first of its class, despite the fact that the original intention and designs for MessagePad were focused on reinventing desktop personal computing rather than designing a device for the mobile professional.

A PDA is generally viewed as a handheld device that provides, as a bare minimum, electronic versions of the functions one would expect of a paper-based personal organiser e.g. diary, calendar, address book, to-do lists, note and memo pads, and clock. Such functionality is often grouped together under the term Personal Information Manager (PIM). The original PIM functionality has been successively built upon so that modern PDAs provide sophisticated, portable computing devices that replicate many of the features of a typical desktop PC machine, including basic office applications such as word processing, spreadsheets, and database functionality.

When looking to define what a mobile phone is we encountered some debate, so the definition used in this report is a hybrid of several sources and is described as 'a portable device which, by using the wireless network, acts as a normal telephone whilst allowing the user to move over a wide area'. Livingston (2004) categorises mobile phones according to their level of sophistication: standard voice-only, Web-enabled, extensible and smartphones. Standard voice-only mobile phones provide a simple form of voice communication and SMS text facilities. Early, Web-enabled phones that use the Wireless Access Protocol (WAP) to gain access to Internet content are being rapidly superseded by extensible phones which can access the Internet and download new software applications, thereby extending the functionality of the phone (Livingston, 2004).

Smartphones are those Internet-enabled and extensible phones which have the basic PDA applications included as well. According to Wikipedia (2004) a smartphone is 'generally considered any handheld device that integrates personal information management and mobile phone capabilities in the same device. Often, this includes adding phone functions to already capable PDAs or putting 'smart' capabilities, such as PDA functions, into a mobile phone.' For the purposes of this report we shall use the term smartphone to refer to a mobile phone that includes PDA functionality.

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[1] Livingston also refers to two-way paging devices, such as RIM's Blackberry, which run on pager networks (which are separate from mobile phone networks). As these products are now being subsumed into the mobile phone segment and no longer use the separate pager network we are not including them in this report. However, the authors note that their reputation for high levels of reliability make them a safe choice for certain application areas e.g. paging medical staff (Lee et al., 2004).

The Personal Media Player (PMP) or Personal Media Centre (PMC) is a relatively new class of mobile device. These systems are focused on media delivery and can play, store and manage a variety of digital media formats. Although first introduced as a mobile method for playing music from compressed MP3 files, this class of device is already being subsumed by the recently released Personal Video Players (PVPs).

A fundamental classification within these three types of devices is between those that are able to connect to the Internet and those that cannot. Livingston (2004) coins the term MIAD: Mobile Internet Access Device. The emergence of technologies such as Wi-Fi (802.11) and 3G which allow such connectivity have opened up a new arena of potential for mobile devices which we shall explore further.

SECTION ONE: Why mobile devices are becoming increasingly relevant to education

Recent changes in device technology and the adoption rates and market development for mobile devices have converged with changes in both the strategic direction of post-16 education and some aspects of pedagogy. This presents an increased need for education professionals to be aware of, and engaged in, the development of the applications and uses of such devices.

The first major driver in this convergence process is the widespread adoption of mobile devices, particularly phones. This is prevalent amongst the core target audience of HE/FE – young people in the 16 to 24 age range. The Learning and Skills Development Agency give adoption rates of 90% for ages 15 to19, and 81% for ages 20 to 24 for 2002 (Attewell and Savill-Smith, 2004) and Brendan Riordan (2003) cites a figure of 86% of students (100% of his target group) possessing a mobile phone.

According to Sarker and Wells (2003), the factors for the widespread adoption of mobile phone technology have not been extensively explored in the literature. However, Ling and Helmersen (2000) have examined issues such as the use of the mobile device within the family as a means of providing security and control, and the balance with the emancipation offered to a young teenager by possession of a device. Clearly fashion, social factors and symbolism (the meaning beyond functionality) that such devices hold in this age group come into play, and Howard Rheingold (2002) believes that the availability of a method of communicating with peers "outside the surveillance of parents and teachers, at the precise time in their lives when they are separating from their families and asserting their identities as members of a peer group" (p. 25) is very attractive. What is clear is that for the young, mobiles have rapidly become a major feature of their lives and a major (if not *the* major) aspirational item (Colmar Brunton, 2002). This year, BBC market research within this age group found that: 'Mobile phones are a necessity not a luxury. 94% have a mobile phone and half of all text messages are sent by the Young [sic] (roughly 10 billion sent in 2003).'

Increasingly, these mobile phones are Internet-enabled. Research from Forrester (2003), indicates that 97 per cent of phones will be MIAD devices - capable of mobile Internet access - by 2008 . Increasingly, as we shall see, these devices will be a hybrid of PDA and smartphone. Universities and other institutions will therefore find themselves being presented with an array of sophisticated mobile devices which the young regard as essential tools for carrying out a range of tasks, including learning.

A second relevant factor is the changing strategic demands of the educational environment. The audience for HE/FE level education is evolving with an increasing emphasis on lifelong learning and the development of new audiences through widening participation (Anderson, 2003). In line with government and funding council strategies, JISC aims to support developments that promote such widening of participation in education. As the JISC strategy 2004-06 points out: 'The widening participation agenda will mean that universities and colleges will be dealing with different types of students, with different expectations and needs. ICT and the use of eLearning techniques will be able to support some of these needs better than more traditional forms of delivering education. ICT can give real meaning to 'learning anytime, anywhere' (2003, p.7).

Becta, (2004), in a study of available research, cites four areas of benefit through the use of mobile technologies: general, student, parent, and teacher benefits. In amongst these areas, specific improvements are noted in motivation (from ‘owning’ a device they can carry around), engagement with learners who may not appreciate more traditional forms, and in writing skills and using just-in-time learning/reference tools for quick access to data in the field. At the moment, most of these benefits have been investigated and explored in the context of schools rather than higher education establishments (see appendix 1 for more information) and it is likely that with the widening participation agenda such explorations will be increasingly required in HE/FE settings.

Finally, it can also be argued that there are strong pedagogical reasons to incorporate mobile learning and the use of mobile devices into educational practices. Developments in pedagogy and learning science have moved towards processes that engage a more active learner using 'constructivist' models, with learners making their own decisions that match their cognitive needs (Farmer and Taylor, 2002). In her case study on the pedagogical advantages of ubiquitous computing in a wireless environment, Susana Sotillo (2003) concludes by saying: 'New developments in wireless networking and computing will facilitate the implementation of pedagogical practices that are congruent with a constructivist educational philosophy.'

SECTION TWO: State of the art in mobile phone and PDA technologies

Before discussing the future development of mobile technologies we present a brief summary of the current state of the art in PDA and smartphone device technologies. However, it is important to note that this is a very fast moving market, with new products being regularly introduced following continual improvements in basic underlying technologies such as memory devices, screen displays and hard disc drives. This summary can therefore be no more than a snapshot of the position in late 2004.

2.1 PDA technology

The main manufacturers of PDA devices are currently PalmOne, Hewlett-Packard, Dell, Sony and MiTAC and together they hold nearly 80% of the market (IDC, 2004).

Processors

The central processing unit (CPU) or processor within a PDA device determines the speed and range of its processing power. As with desktop PCs the processing power of a unit is generally measured in the speed of the CPU as measured in mega-hertz (MHz) or giga-hertz (GHz). There are three main manufacturers producing processors for such devices: Intel, Motorola, and Texas Instruments. Other manufacturers licence designs from third parties e.g. Sony's 'handheld engine'. As processors develop they increase the speed of processing, extend the range of applications that can be processed, and allow extra hardware features to operate, for example, newer displays such as thin-film transistor (TFT) colour displays (see 'displays', below). PDAs are presently equipped with processors running from 66MHz to 600 MHz.

Intel's PDA processors are based on one of two technologies: StrongARM or XScale. Intel's StrongARM processor family revolves around its 'flagship' microprocessor, the SA-110. However, StrongARM is in the process of being retired and replaced by XScale chips with a 400MHz processing capability – an increase of nearly 200 MHz. In addition, Intel now recommends opting for an XScale based PDA rather than ARM as it allows more efficient use of battery power (PC World, 2004).

Intel has also recently launched a new Bulverde chip to take the processing speed up to 600Mhz. This chip also integrates a 'wireless trusted platform module' (WTPM), which is Intel's hardware companion to Microsoft's Next Generation Secure Computing Base (NGSCB). This is likely to become important as new Windows software is developed.

Motorola processors, now produced under the Freescale Semiconductor banner, include the DragonBall VZ (an enhanced version of the EZ), Super VZ (which is faster than the VZ and supports more features) and the new MX1 (Media Extensions). This last is important since it is the first chip by Motorola to be based on the ARM9 technology instead of Motorola's proprietary core architecture.

Texas Instruments produce the OMAP processor series. The OMAP 1510 processor first appeared in Palm's Tungsten T device in late 2002, while the OMAP 310 is used in several of

Palm's entry-level PDA devices. These processors are also used widely in mobile phones, particularly Nokia smartphones.

Memory

Currently PDAs do not possess a hard disc drive. This means there is a danger of losing data if the battery runs down completely. They store basic software programs (address book, calendar, memo pad and operating system) in a read-only memory (ROM) chip, which remains intact even when the machine shuts down. A PDA's Random Access Memory (RAM) memory is used to temporarily store data whilst processing applications and as the long-term file store for documents, pictures etc. At the time of writing, PDA devices range in memory from 8MB to 256 MB. Some newer models, such as the recently introduced Tungsten T5, have flash memory, which does not fade with loss of battery power. This allows these to be also marketed as portable storage devices (Palm, 2004). Larger memory sizes are particularly important for media-based file manipulation.

Expandable memory

Extra (expandable) memory can be plugged in to a PDA device through an expansion slot. Media applications that store and process digital pictures and MP3 files will require the use of such expansion. There are currently three types: Sony's Memory Sticks, CompactFlash cards, and MMC/SDIO media. These types of devices, resembling mini credit cards, currently have a range up to about 1GB of storage.

Battery power

PDAs typically use rechargeable batteries (based on lithium ion, nickel cadmium, or nickel metal hydride) and battery life can vary from two hours to two months depending upon the PDA model, its features, and how it is used. It is worth noting that it is especially important to back up data on a PDA since running a battery completely down will result in the loss of a user's data (unlike a PMP, which uses hard disc storage so does not lose data). PDAs are generally recharged from the mains through an AC adaptor or a cradle with an adaptor.

Input and Keyboards

A large number of PDA devices use a 'pen' or stylus-based input system for handwriting recognition. However, handwriting recognition systems have limitations, so there are several handhelds with built-in QWERTY keypads. These tend to consist of very small button-style keys which introduce problems for some users, although one can purchase an external, foldable keyboard. Some models also display a virtual keypad on the display screen, again with small keys, which can be tapped with the stylus (for more information see appendix 1).

Displays

With a typical size of around three inches (7.5 cm) the display screens of PDAs are smaller than laptop or PC screens, but even entry-level devices now boast colour screens. The screen resolution is the important feature with regard to display quality, and industry commentators recommend a minimum of QVGA (320x240 pixels). Modern screens are based around transflective thin-film transistor (TFT) technology which provides a good display surface both indoors and out. For indoor use, some PDAs provide a backlight for illumination.

Data synchronization or 'syncing'

PDAs were initially designed to be satellites to a desktop PC system. Many users continue to have a desktop PC machine and a mobile device, and use the latter when travelling about to act as a PIM and document carrier which they and then synchronize with the desktop machine later on. This is typically done through a serial or USB port on the PDA, although some PDAs also have a cradle that they sit in while hooked up to the PC. Given the mobile nature of PDAs and the potential for loss of data when batteries run down, most users also regularly back-up all their data with a desktop system.

Connectivity with InfraRed or Bluetooth

Most PDAs also have an infrared data communications port that uses infrared light to beam information to a PC or another PDA, and specifications for these protocols are developed by the Infrared Data Association (IrDA) – see appendix 1 for more details. As this technology uses light it requires line-of-sight between the two devices. The alternative, Bluetooth, allows devices to communicate over short distances (up to 10m) using low bandwidth wireless connections at speeds of typically 56 to 721 kilobits per second (kb/s). The technology is a replacement for cables and is used to connect to a network or printer, or to synchronise a PDA device with a desktop PC or mobile phone.

Wireless

A Wireless Local Area Network allows a mobile user to connect to a local area network (LAN) through a wireless (radio) connection at speeds of up to 54 Mb/s. A short-to-medium-range high-bandwidth radio transceiver is required on the mobile device. The distance between the mobile device and the source of the wireless LAN varies greatly depending on the infrastructure (e.g. thickness of walls) within a given building. The IEEE 802.11 standard specifies a range of technologies for such wireless LANs (IEEE 802 LAN/MAN Standards Committee, 2004). Wireless LAN devices are currently built using 802.11b – more commonly known as Wireless Fidelity (WiFi), although products based around the faster 802.11g standard are becoming available and this is recommended by JISC (2002) as a future upgrade route.

Music and Audio

Many PDAs can now play MP3 music files through standard 3.5mm stereo headphone plugs. Some devices, aimed at a business audience, also have built-in voice recorders.

Cameras and video

A number of the newer PDA devices incorporate digital cameras, for example, the recently released Zire 72 provides 1.2 mega-pixel pictures (1280x960) and also video (320x240). Many devices can also play back short video clips (in a variety of formats e.g. MPEG, QuickTime, AVI).

Global Positioning Satellite (GPS)

GPS devices are capable of using the Global Positioning Satellite system to identify the user's current location. Example manufacturers include: Garmin, Magellan and Benefon. These devices are generally targeted at the outdoor enthusiast and the mobile, on-the-road user, and can be plugged into the serial interface of a PDA device. When combined with digital map technologies such as Anquet Maps or Memory Maps, a user equipped with a GPS-enabled PDA can view, in 3D, a graphical representation of exactly where they are in the UK and see a 3D representation of the topography around them. It is also possible to see an interactive picture of a mountain or valley and to do a 'virtual fly through' of the route you are planning.

Operating Systems

Most PDA devices are presently based on one of five major operating systems:

- Palm OS (for Palm, Sony Clie, and the Handspring range of devices)
- Windows Mobile (formerly PocketPC), a cut-down version of the Microsoft Windows desktop system
- Symbian Operating System (used primarily for Smartphone products such as the 02 XDA)
- Linux
- Blackberry Operating System (Dedicated Mobile Email communications devices)

2.2 Smartphone technology

As hybrids of mobile phones and PDAs, Smartphones have many similarities with PDA devices and use some of the same technologies.

Telephony

The most important feature of a smartphone is the ability to make mobile voice calls over one of the cellular mobile networks. These networks use the GSM900 or GSM1800 frequency standards for voice and data calls. All smartphones support both types – known as dual-banding – and increasingly offer support for GSM1900 which is used in North American markets. The network services are provided by a range of operators (for example, in the UK, Vodafone, Orange, O2, T-Mobile) and buying decisions are often driven as much by the network pricing models for telephone calls as by the features of an individual smartphone.

MMS

Multimedia Messaging Service (MMS) is the enhanced version of SMS text messaging services that allows photos, videos, graphics and sound to be included with a text message transfer. All smartphones and some PDAs support MMS and smartphones, like PDAs, often have built-in cameras and video recorders with limited video playback.

Processors

Smartphones are based around the ARM range of processors such as StrongARM, with speeds of around 200MHz, but will be moving over to XScale in line with PDAs.

Operating Systems

Operating systems active in the smartphone market are: Symbian, Windows Mobile OS, Palm OS and Linux.

Memory

Smartphones have similar memory arrangements to PDAs, with a typical 128MB RAM and 64MB ROM. Like PDAs they do not have hard disc drives.

Wireless/3G/Bluetooth

Smartphones allow wireless connection to the Internet through the data-enabled aspects of the mobile phone network. GPRS (General Packet Radio Service) is the standard technology for accessing high speed data through the mobile phone networks and all smartphones support this protocol. This is a different technology to that of WiFi wireless networking. The GPRS system is packet-based, like the Internet's basic TCP/IP protocol, is always on, and offers speeds of up to 24kb/s. Phones are being released in 2004 that include support for 'next generation' data calls using third generation (3G) data technologies which offer data speeds of up to 384kb/s. This was recently only supported by the 3 network, but other networks such as Orange and Vodafone are now bringing 3G services online. Smartphones also come equipped with Bluetooth.

2.3 Personal Media Players (PMP)

This relatively new class of device focuses on the storage and play back of digital media whilst on the move. Initially supporting audio formats (e.g. the Apple iPod), increasingly they also offer high quality video (MPEG-4 standard), as well as connectivity to PCs and home entertainment systems. Unlike smartphones and PDAs these devices do provide hard disc storage (between 20 and 80GB). The video players incorporate a 3.5" TFT colour display. Examples of key products in the market include ARCHOS AV320 Video Recorder and the Apple iPod.

The different audio formats fall into one of two basic classes of audio format: one in which data is digitally compressed and the other in which it is not. Compressed formats include Advanced Audio Coding (AAC), MP3 (8 to 192kb/s) and Windows Media Audio (WMA). Uncompressed formats include Windows uncompressed audio format (WAV). The devices that play back video support a range of compression formats, for different levels of video definition, e.g. MPEG's standards for compressed video (MPEG-1, MPEG-2 and MPEG-4) and Audio Video Interleaved (AVI).

These products connect to PCs, hifi stereos and video equipment through a range of connectors including FireWire 400, USB 2.0 and MiniDIN sockets for S-Video.

SECTION THREE: Future technology trends in mobile devices

3.1 Short-term trends (up to five years)

Wireless Networking

Trend Summary: *Wireless technology in general is set to become cheaper, faster and much more common over the coming year as more home users and institutions deploy or adopt Wi-Fi kits to share lines and devices around the house or within the workplace. Newer standards will allow wireless broadband data speeds over short distances and the development of wireless metropolitan networks. These networks will develop so that a user can log in through any wireless network.*

There will be continuing developments in wireless Local Area Networks (WLAN), which allow mobile workers with 802.11b-equipped devices to link to Internet-based services and corporate networks. Individual WLANs provide relatively small areas of access through a particular node or point, known as a wireless access point. These are sometimes termed 'hot spots'. Increasingly, manufacturers and ISPs are working together to provide wireless roaming between such hot spots. These developments allow a user to move between different providers of wireless area nets without having to manage new username and password identification (Anton et al., 2003). Wireless ISPs (WISPs) agree to co-operate and allow a central clearing house to maintain lists of individual's identification tags associated with their laptops or mobile devices. A user, on entering a particular Wireless LAN provided by a WISP, will connect to the local access point and their tag will be forwarded via the clearing house, to the user's home WISP, which will authenticate. The Wi-Fi Alliance is a nonprofit international association formed to assist this process and to certify interoperability of wireless Local Area Network products based on the IEEE 802.11 specification (see appendix 1).

As part of the UK's contribution to this process, the Janet Wireless Advisory Group will be building such a central clearing system known as the National Remote Authentication Dial-in User Service (RADIUS). The work, part of the Location Independent Networking (LIN) trial being run by UKERNA is due to commence in 2005 with a trial period of 6 months (Sanker, 2004). One of the aims of LIN is to reduce the complexity that a guest user encounters when getting access to a specific network location.

Hand in hand with developments on wireless authentication will come developments in networking speeds driven by newer 802.11 standards (IEEE 802 Standards Committee, 2004). For example, integration of the faster 802.11g technology is likely in the near future. Networking with 802.11g is at a speed of 54Mb/s and requires more battery and processing power than is currently available (see, however, battery life below). In the meantime, WMM (Wi-Fi Multimedia) will start appearing in consumer products in 2005. This enhances 802.11 by prioritizing information that is sequential and time-dependent such as a video (Smith, 2004).

A driver in the market place is the desire to deliver High Definition digital TV and streaming video through wireless networks. Therefore, much faster wireless speeds are likely from around 2006 onwards as newer standards like 802.11n are refined and adopted. The standard is still being discussed (Deffree, 2004), but one version would provide more than 250Mb/s of bandwidth using techniques to compress data more efficiently and by using antennas that would allow it to transmit more than one signal at a time. In addition, UltraWide Band (UWB), a short-range radio technology, is being developed to relay data from a host device to other devices in the immediate area (up to 10 metres or 30 feet) (Intel, 2004). However, there have been some issues with the development of the standards process, centred around different views of the technology (multiBand OFDM or Direct Sequence UWB) and these discussions are on-going (Meade, 2004).

In addition, for wider area coverage, the IEEE is also developing the 802.16 WiMAX wireless broadband standard. WiMAX will offer wireless connectivity at up to 30 miles from an antenna at speeds of up to 75Mb/s and act as competition to fixed line cable modems and ADSL connections. Such wireless broadband may also provide serious competition to the 3G mobile phone network operators and will be particularly useful for remote locations. This standard is expected to help the development of wireless broadband metropolitan-area networks by 2010 (Diaz and Takahashi, 2004). For more information on WiMax see appendix 1. At the other end of the scale of coverage there will be continuing developments of Bluetooth technology to facilitate Wireless Personal Area Networks (WPANs). These networks, which are handled by the IEEE 802.15 standards group (IEEE, 2002), aim to eliminate cables between mobile devices and their peripherals over small geographical areas (less than 10m).

At the same time as these developments there will be technological improvements in the cellular networks that provide voice and data calls to mobile and smartphones. These networks are cellular in that devices communicate from within a geographically defined area, or cell, back to a base station (a mobile phone mast). Currently, manufacturers of phones are installing and marketing third generation cellular technologies, known as 3G, which uses a mixture of IP and Asynchronous Transfer Mode (ATM) technologies. Fourth generation, or 4G, will follow in the next few years.

Although still under development 4G phones will be entirely IP-based, which supersedes the cell model by providing peer-to-peer networking where each mobile device acts as a transceiver and a router/repeater for other devices with no need for central base masts or stations (Hui, 2003). 4G is more robust as it is less centralised and will provide faster speeds of up to 100Mb/s. Increasingly, it will be in competition to local wireless networks providing similar speeds.

Convergence of device types – the introduction of PACE

Trend Summary: *Mobile devices are likely to converge into a hybrid of smartphone, PDA and media technologies, which can be termed a PACE (Personal Assistant, Communication and Entertainment) device.*

Whilst there is a strong trend towards convergence between classes of device, it is difficult to predict whether the end point will be a single appliance or a range of devices offering differing subsets of technologies (Sharples and Beale, 2003). There are powerful arguments for the former as it is likely that growth in the market for PDAs without communications capability will continue to be flat and even decline, despite lower prices. PDA shipments shrank worldwide by almost 5 per cent in the first quarter of 2004 compared with the same quarter last year, according to Gartner (Hoffman, 2004). Analysts predict a market increasingly dominated by smartphone devices since there is a very large base of mobile phone users willing to upgrade (Blau, 2004). The huge number of users of increasingly sophisticated mobile phones, when compared to those with a PDA device, leads some observers to believe that smartphones and their manufacturers will become the dominant players in a market for mobile devices (Wintergreen Research, 2003). Indeed, Sony, who market the Clie range of devices, recently announced that they would be pulling out of the PDA market outside Japan (IDC, 2004).

Future versions of these devices will increasingly involve a convergence of our existing classes of items, smartphones, PDAs and PMPs, and will combine the key functionalities of each type of device: information, organisation/productivity, entertainment and mobile communication (Werbach, 2001)[2]. Such a device, which may be termed a Personal Assistant, Communication and Entertainment (PACE) device can be traced from its ancestors in early PDA and mobile phone technology. The move towards such a convergence is built on three key trends – the increasing sophistication of the processing capability of smartphones, the incorporation of networking and phone capability into PDA devices (for example, the Palm Treo), and, finally, the developments in very small hard disc drives evident from devices such as Apple iPod. Past attempts to use these spinning disks in PDAs encountered problems because the drain on the batteries made them impractical. However, Toshiba and other drive makers have now developed ultra-low-power disks small enough to fit in the SD card format.

The integration of these small hard discs into existing PDA and smartphone technologies will allow large scale manipulation and storage of digital media as is currently available through PMPs, and as part of this process we will see a rapid convergence of PACE devices and TV. Motorola, NEC, Nokia, Siemens, and Sony Ericsson Mobile Communications have launched the Mobile Broadcast Services initiative organized under the umbrella of the Open Mobile Alliance (OMA – see appendix 1 for more information). They are establishing mobile service specifications to ensure interoperability of services across countries, operators, and mobile terminals. New phones, that can connect to broadcast TV as well as mobile networks, will be available in 2005 (Blau, 2004) and trials have already commenced in the UK for a digital TV technology known as DVB-H (3G news and information, 2004). By 2007 the market will also be introducing High Definition TV on mobile devices. It is likely that the signals for both these TV technologies will be delivered by a separate antenna or satellite-based network rather than through existing mobile networks. Clearly, the market in mobile entertainment technology will be a key driver in future developments, but the introduction of PACE devices may also herald the introduction of media-rich personalised learning devices.

The potential for Apple to build its PMP upwards is strong and rumours abound, for example, over the introduction of video viewing (see http://www.appleinsider.com/article.php?id=454 [last accessed 25/10/04]). Currently, one can store contact names and addresses on the iPod, but only update them on a connected PC. Information from desktop applications (including Microsoft Entourage, Palm Desktop and iCal) can be synchronized. As analyst Jakob Nielsen recently told The Financial Times: 'As the pods go up in gigabytes, it's inevitable that they will become general purpose storage devices. Add a colour screen and they become photo viewers. PDA-type features are a convenient adjunct to these devices and that convergence is inevitable.' (quoted in Macworld, 2004).

[2] Or as Sony proposed for their CLIE - Communication Link Information Entertainment.

However, other commentators believe there will not be convergence at this level (Werbach, 2001). It may be that we get developments more in tune with Donald Norman's vision of the information appliance. Norman's vision was centred around a device specialising in information: knowledge, facts, graphics, images, video or sound. In his definition, an information appliance is designed to perform a specific activity, such as music, photography, or writing, and a distinguishing feature of these devices is the ability to share information among themselves (Norman, 1999). We may therefore see an alternative trend towards simplification, particularly in the mass market end, with the Apple iPod presenting an example of the fashionable, functional, yet easy to use mobile device of the future.

Major hardware and software trends

Trend Summary: *Battery life will be extended and provide more power through the introduction of fuel cell technologies. New screen technologies will become available.*

Battery Life

The battery found on most recent Pocket PCs and Smartphones is the Lithium Polymer-a rechargeable Lithium Ion battery that can be manufactured in different shapes and sizes. These batteries have limitations both in overall lifecycle and the levels of power provided (Red Herring, 2004a). Japanese mobile phone makers are behind developments for new types of fuel cells in their drive to add digital TV broadcast tuners to their phone models, as this uses considerable power. Several companies are now working on fuel cells that would power mobile devices by generating electricity from oxygen and such fuels as hydrogen or methanol. Hitachi's Direct Methanol Fuel Cell (DMFC) for PDAs is on target for sale in the second half of 2005 (Kallender, 2004). By refilling the fuel, these cells should provide more power to PDAs without the need for batteries or rechargers.

Screen technologies

As the operating systems of devices develop they will support even more diversity in screen sizes and shapes. A new display technology is the Organic LED (OLED) screen which allows displays to have a simpler and thinner design, higher refresh rates, and a self-luminescence that eliminates viewing-angle issues. There is also some development towards pull-out or roll-out screens, allowing a very small device to be carried around but to be set up as a lap-top size system (E Ink, 2002).

Software Trends

At the time of writing, Windows Mobile and PalmOS are battling to obtain the major market share in PDA operating systems, whereas Symbian and Windows Mobile are fighting over the ground for high-end smartphones. Many commentators believe that as the PDA market is in serious decline, the increasing sales of smartphone devices will mean that the arguments over the operating system platform for mobile devices will be between Symbian and Windows. However, almost all the current, low-end (i.e. non smartphone) mobile phones are installed with the mobile phone manufacturer's proprietary OS so it is fair to say that there is a serious third contender and that the choice between Symbian and Windows is by no means a closed contest

(Red Herring, 2004b). If we do see significant convergence between PDAs and smartphones led by mobile phone manufacturers then their decisions over the choice of operating systems will dictate the direction of the mobile device's applications' software provision.

The smartphone manufacturers themselves seem keen to resist Windows becoming the OS of choice on mobile platforms as many of them are key investors in the Symbian system (e.g. Nokia, Samsung and Ericsson). Symbian is based on open standards and is developed in a wide range of languages and hence is arguably a platform more conducive to open source application development.

Linux for mobiles (Embedded Linux), whilst fourth according Gartner figures, currently only has a very small market share of 1.9% (ByteEnable, 2004). There is a small number of PDAs which ship with Linux installed, for example, Sharp Zaurus SL-6000, whereas other devices can be reprogrammed with Linux. As Linux gains ground in corporate markets, particularly if IBM continues to support its development, then we may expect to see more uptake of the embedded version in mobile devices.

The availability of applications and office packages such as word processing is not particularly dependent on the operating system installed on a mobile device. Windows Mobile devices obviously have the benefit of cut-down versions of well known Office packages and these will continue to track their parent products. However, PalmOS devices can work with Office application documents using packages such as 'Document-to-go' (Mossberg, 2003). The introduction of xhtml-based browsing on smartphones (as opposed to older WAP-based browsing), for example through the Opera browser, opens up new possibilities for software based around Web services technologies. Software to allow PDAs to be used as e-books, for example, Mobi Pocket, will continue to be refined.

We are also likely to see an increasing number of applications based around voice recognition, although this is because car drivers are seen as an important market segment, rather than a concern with accessibility issues (Gill, 2004).

3.2 Medium term trends (three to ten years)

Wearable Computers

As miniaturisation continues, mobile devices will increasingly be worn either like watches or glasses or even woven into fabrics as an integral part of clothing. The TSW report "Evaluating the development of wearable devices" provides more detail (de Freitas and Levene, 2003).

On a longer timeframe the possibilities of implanted mobile technologies begin to present themselves. VeriChip, an implantable computer chip about the size of a grain of rice, has just been approved by the US FDA (Associated Press, 2004); in the UK, Professor Kevin Warwick, although controversial, has obtained worldwide media coverage for his experiments in implanting computer technologies into his own nervous system (Warwick and Gasson, 2004).

Seamless networks and mobile networking

‘In mobile networking, computing activities are not disrupted when the user changes the computer's point of attachment to the Internet. Instead, all the needed reconnection occurs automatically and noninteractively.' (Perkins, 1997, online).

Seamless networks will be built on the work being undertaken to allow WISPs to sign on to each other's clients through centralized authentication services (see 'wireless networking' section). It is likely that future PDAs/smartphones will be able to automatically connect to either a Wi-Fi, WiMax or mobile phone network such as 3G or 4G depending on the most cost effective connection available in the locality at a particular time. This changes the focus from loss of coverage (for example, 3G services will use GPRS when 3G is not available in a particular area), to seamless selection of the cheapest or fastest network within an area. It is also possible that 4G will allow integration of a range of access methods so that different networks can be used *simultaneously*, for example, making a telephone call about going to see a film at the same time as accessing an online review of the film via a local wireless network (Hui, 2003). An early example of the potential for seamless networks is the introduction of IPOne's AirGate 2000N 802.11 WLAN Card which can conduct Wireless LAN roaming with commercial cellular networks for 2.5G and 3G.

Work is also being undertaken to allow seamless connection of mobile devices to the Internet. Mobile IP (Perkins, 1996), a standard proposed by a working group within the Internet Engineering Task Force, was designed to solve problems with this type of connectivity by allowing the mobile node to use two IP addresses: a fixed home address and a care-of address that changes at each new point of attachment.

This development will be partly driven by a new technology known as Soft Radio. Soft Radio or software-defined radio is a 'frequency-agile' communications technology i.e. it can work with any of the radio-spectrum frequency bands now used for different types of data communication e.g. 3G, GPRS, WiFi, WiMax. A mobile device incorporating soft radio would use software, rather than hardware, to handle the radio signal processing – and be reconfigurable with new software. For more information see appendix 1.

SECTION 4: Issues for HE/FE

4.1 Infrastructure

Over the coming years increasing numbers of students will be presenting a variety of mobile devices and will expect to be able to use them within the university network infrastructure. These devices will be wireless-enabled using WiFi, and at a later date, support WiMax and other protocols. This will present campus ICT managers with many issues concerning the provision of additional hardware and software support. There may need to be a dedicated server to handle connection of PDA and mobile devices within a campus, and at a national level work is already under way on a set of central, authentication-clearing servers for wireless networks (Sanker, 2004).

This trend may also lead to a significant shift from supporting a lab-based PC infrastructure to supporting wireless access to the network from a student's own hardware. Obviously such a move will present new support issues. Synchronisation with network servers is an issue. A fundamental problem is the potential lack of homogeneity as a multitude of devices is made available. This is particularly acute for the software developers of learning applications who must target a range of possible devices (Roschelle, 2003). Should the student body be 'coerced' to conform to a particular standard? Might that not be better facilitated by the college providing, on loan, the necessary hardware (for example, in Wichita, US, medical students are provided with Sony Clie T615 handhelds and a 32 Meg Memory Stick (University of Kansas, 2003)? If not, then what about students who do not have access to such devices? Will a 'digital divide' occur in Higher education? (MacGillivray and Boyle, 2002).

4.2 Staff training and awareness

Staff in HE/FE are likely to need training and awareness in mobile and PDA technologies. Staff who are less technically aware may have little, if any, comprehension of what is possible with newer mobile devices. As an example, experience from the University of South Dakota suggested staff training was a key issue to the successful use of PDAs (Smith, 2003). Pressure for adoption is likely to come from the student body, who will increasingly be handling such devices and using them as support tools in an *ad hoc* fashion during courses.

The widespread use of the mobile phone as a social tool, including the physical sharing of phones between teenagers, may provide a foundation for newer forms of intensive collaborative learning. The implications for the collaborative nature of such devices need to be explored further by the HE/FE community. As Rheingold (2002) points out there is a somewhat subversive element to the adoption of mobile devices. Such subversive motives may impact on the educational nature of the use of these devices. As an example, the practice of instant messaging between mobile device users during lectures (so-called 'back-chat') can have good and bad consequences: possibly promoting greater knowledge sharing but also providing a platform for mis-information to be promulgated without challenge and even 'public' ridicule.

4.3 Usability

Small screens, fiddly keypads and handwriting recognition all present issues of universal accessibility. JISC's TechDis service have explored these issues in more depth (TechDis, 2002). The developers of software applications for learning will need to consider these issues in depth during the development process (Lee et al., 2004).

4.4 Legal and privacy issues

The large numbers of mobile devices and their wireless capability is likely to present legal issues for ICT departments. If the devices are actually owned by students themselves, what levels of control can be implemented with regard to security options and privacy issues? These devices are relatively easy to lose and are likely to attract attention from thieves. A recent survey found that two thirds of PDA users do not use any kind of encryption to protect data, and use them to store valuable personal information such as bank account passwords, PIN numbers and access codes for secure buildings (Computer Business Review, 2004).

There are also outstanding issues over the security of communication over wireless networks and these are likely to gain importance (UKERNA, 2003). The deployment of a wireless infrastructure can provide an unregulated 'back door' into an internal network. As a minimum, it is generally recommended that data transmitted over wireless connections are encrypted using the Wired Equivalent Privacy (WEP) security protocol, although this requires additional resources at the client and server ends of a system, and has some weaknesses (Arbaugh et al., 2002). Other security mechanisms such as password protection, use of virtual private networks (VPNs), and authentication should also be considered. This is particularly pertinent in the area of medical education in which a patient's notes are accessed through devices.

Undoubtedly, there are copyright issues with regard to the use of these devices as media players and, increasingly, digital rights management is a key issue within ICT. And what of the information universities will gain about students, for example their location, as they log in and out of a multiple number of wireless networks? New ethical frameworks for ICT usage will need to be developed.

4.5 Business process re-engineering

The availability of this technology makes new ways of administering universities an option. As with the introduction of other forms of information technology such changes may require a review of the processes themselves. For example, using the push nature of SMS to issue SMS reminders of library loans will require some rethought on the lending process in general. Livingston provides an example in remote access to staff directory services (Livingston, 2004). Here in the UK the issue of immediate transfer of test scores via SMS has been explored by a team at Wolverhampton University (Riordan, 2003).

4.6 Pedagogy

We have already touched on the issue of newer forms of teaching and learning that can be facilitated by the increasing use of mobile devices. Collaborative learning and a more constructivist approach to education are, according to some educationalists, facilitated by the use of mobile devices. Existing forms of computer-assisted learning can be enhanced by using mobile devices, particularly through the ease with which aggregation of information gained within a classroom about students existing knowledge (e.g. through short quizzes) or from collaborative data gathering (e.g. fieldwork) can be facilitated (Roschelle, 2003). Newer forms of Web-based social communication such as weblogs and wikis may enhance collaborative learning, help develop communities of practice within classes, and work 'with the grain' in the manner that younger adults now communicate (Kelly, 2004).

At the same time we should also not lose sight of simpler, but effective, pedagogical benefits of mobile technologies, for example, the ease with which a part-time (employed) student can carry lecture notes around on a PDA as opposed to carrying a pile of papers and books whilst at work. Self-assessment by students whilst away from the campus is also seen as a growing area for development (see appendix 1 information concerning the Robert Clark Centre). Increasingly, mobile devices are being used to facilitate field work and to support learning in professions where such devices are widespread–a key example is the education of medical staff in the US (Smith, 2003). Further details of US projects can be found at EduCause's Resource Centre pages for PDAs (EduCause, 2004). In the UK, Glasgow Caledonian is developing support through mobile devices for Business School students who are on placements or learning at a distance (Trinder, 2004). The 'beam' or infrared feature of some PDAs can be used for collaboration in classroom. These new ways of working will need to be explored in more depth. It is fair to say that schools seem to be leading the way although initiatives are getting off the ground in the HE/FE sector (e.g. Oxford's 'Rambles' project).

A more 'bread and butter' issue is that of migration of materials from central learning repositories to various device types and locations (see also 'deployment' below). The devices have smaller screens than conventional PCs and the specific design of e-learning materials for PDA or PACE devices is likely to become an unsustainable practice on a larger scale. Early experiments in the use of PDAs in the USA have indicated that the design of such materials and the range of e-learning applications were seen as a shortcoming, for example, in the PDA initiative at the College of Science and Engineering at the University of Minnesota Duluth (Allen, 2004). The republishing of existing content from e-learning infrastructures, such as a VLE, into multiple platforms is a more sustainable solution. It may not make sense to re-publish heavily text-intensive materials to today's existing devices (Livingston, 2004), but this is likely to change when larger screen devices or roll-out electronic paper become available. Some experimentation is being undertaken within the HE/FE community, for example, using Bodington to deliver materials to a PDA (Trafford, 2004). It may be that a more workable solution involves republishing VLE material through an institution's content management system (which is more likely to be able to automatically repurpose content to mobile devices) (Ramsden, 2004). How though will a thorough programme of testing on a range of devices be implemented? We will also see an inevitable demand for these materials to be media-rich and comparable to the experiences of the rich media environment provided by PMP devices with, for example, increases in streaming video.

4.7 Development and deployment

There is a wide range of development and deployment issues with regard to the introduction of new e-learning and administrative applications using mobile technologies. A discussion of these issues is beyond the scope of this report, but Lee's text (Lee et al., 2004) is a key resource in this area. The authors make clear that deployment of such systems can be expensive, technically difficult, and fraught with difficulties related to connectivity and ergonomics. Such systems cannot be designed in a vacuum, divorced from ‘mainstream’ business and educational systems and must pay particular attention to the usability issues inherent in designing for smaller devices (particularly screen display size). There is also a range of issues regarding network infrastructure, such as the use of firewalls and the encryption of data between applications and database servers (using SSL, for example).

4.8 'Always on'

The rapid development of seamless networks connected to a range of mobile devices, which one may even be wearing, presents new challenges with regard to work/life structures. The ‘always on’ nature of these technologies will present consequences for society in general, but education, with its younger user-base, may face such challenges sooner rather than later. The boundaries between a student's educational time and the rest of their lives will increasingly blur (Ling and Yttri, 2002). There may be less time for reflection at the expense of response. These are longer-term issues that will need further exploration.

Conclusion

This report has reviewed the current state of the art with regard to mobile devices and suggested some trends for their future development and use within HE/FE. Students and staff are increasingly likely to be in possession of at least one mobile device and in the near future all these types of increasingly powerful computing devices will be capable of seamlessly connecting to the Internet through a variety of local and metropolitan wireless networks and a range of third generation cellular networks. These devices will effectively be 'always on' the network. This development presents education with a number of opportunities to enhance learning, administration and research, but also presents new challenges for the management and support of university infrastructure.

In addition, the markets and technologies associated with these devices are changing rapidly. If the different device types currently on the market converge on a single type then the difficulties associated with a lack of homogeneity will be minimised. If this does not happen then institutions will be presented with difficult decisions concerning the integration of their existing systems with a wide range of smartphones, PDAs and media-playing devices. At the same time there will be pedagogy issues and concerns over security and privacy of information. All these opportunities and challenges will need further work. To date, most work on the use of such devices in UK education has been undertaken in the schools sector, but increasingly, higher and further education will need to take up the baton.

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Appendix 1 – Further information

Links to information on consumer products is provided to give insight into the types and range of products – it is in no way intended as an endorsement of those products.

Input devices and keyboards

Virtual keyboards

1. For insight into some of the issues surrounding the use of **laser-projected virtual keyboards**, see the ZDNet UK review of the I.TECH virtual keyboard [last accessed 22/10/04]:

http://reviews.zdnet.co.uk/hardware/inputdevices/0,39023905,39165419,00.htm

2. Not laser-projected, the Senseboard® **Virtual Keyboard** takes a slightly different approach [last accessed 22/10/04]:

http://www.senseboard.com/

3. **Onscreen virtual keyboards** can be designed for specific purposes and users with specialist requirements. See the Mountfocus website for a description of what they claim to be able to do [last accessed 22/10/04]:

http://www.virtual-keyboard.com/

Wireless, foldable keyboards

1. The Targus Universal Wireless keyboard uses infrared and is one of the largest external keyboards for handheld devices. Read the ZDNet UK review at [last accessed 22/10/04]:

http://reviews.zdnet.co.uk/hardware/inputdevices/0,39023905,39171025,00.htm

2. More convenient that infrared, the Stowaway Universal Bluetooth keyboard does not require a line of sight, but does, of course, require you to have Bluetooth. Read the ZDNet UK review at [last accessed 22/10/04]:

http://reviews.zdnet.co.uk/hardware/inputdevices/0,39023905,39167418,00.htm

Thumbpad keyboards

Smaller than a foldable keyboard and only really suitable for short periods of use, thumbpad keyboards can be clip-on or wireless, but tend to be produced for a specific handheld device rather than being 'universal'. As an example, see:

http://www.mrgadget.com.au/catalog/product_info.php/cPath/27_62_75/products_id/384

Guidelines, specifications and standards associations

Infrared Data Association (IrDA)
http://www.irda.org/index.cfm

The IrDa is an international, nonprofit organisation and was set up in 1994 to develop specifications for infrared wireless communication. It operates through a series of Special Interest Groups and Committees and lists Warwick University as the UK HE member.

Wi-Fi Alliance
http://www.wi-fi.org/

The Wi-Fi Alliance is an international, nonprofit organisation set up in 1999 to certify the interoperability of wireless Local Area Network products based on the IEEE 802.11 specification. There are no UK HE/FE members listed on the website.

Open Mobile Alliance (OMA)
http://www.openmobilealliance.org/

The OMA was set up in 2002 WHAT IS THERE DEFINITION OF OPEN? IS IT WHAT WE WOULD NORMALLY UNDERSTAND IT TO BE?

Software-defined radio (Soft Radio)
http://www.sdrforum.org/index.html

The SDR Forum is an international, nonprofit organisation dedicated to developing requirements and/or standards for SDR technologies.

Further Reading

WiMax

For more information on WiFi, WiMax and 802 see the ZDNet white paper **Wi-Fi, WiMAX and 802.20 - The Disruptive Potential of Wireless Broadband** [online] available at: http://whitepapers.zdnet.co.uk/0,39025945,60090078p-39000516q,00.htm [last accessed 24/10/04].

4G

For a good overview of 4G, see Andy Dornan's article 'Fast forward to 4G' [online] available at: http://www.networkmagazine.com/article/NMG20020304S0010 [last accessed 24/10/04].

Battery Life

Red Herring, 2004a. *Smart phones' power problem*. **Red Herring** [online]. Red Herring Inc: California. Available at (requires registration): http://www.redherring.com/Article.aspx?a=1613&hed=Smart+phones%e2%80%99+power+problem [last accessed 24/10/04].

Constructivist Education

TAYLOR, J., 2003. **A task centred approach to evaluating a mobile learning environment for pedagogical soundness.** MOBIlearn IST project public results paper. Available online at: http://www.mobilearn.org/results/results.htm [last accessed 25/10/04].

BOUDOURIDES, M., **Constructivism and education: a shopper's guide.** *International Conference on the Teaching of Mathematics.* Samos, Greece, July 3-6, 1998. Available online at: http://www.math.upatras.gr/~mboudour/articles/constr.html

Case studies of research done in schools

Becta's research portal is a good source of case studies and reports on the use of PDAs in schools. Key texts used in the production of this TechWatch report were:

PERRY, D., 2003. **Wireless Networking in Schools: a decision making guide for school leaders.** Specialist Schools Trust: London. Also available online at: http://www.becta.org.uk/page_documents/leas/wire.pdf

PERRY, D., 2003. **Handheld Computers (PDAs) in Schools. BECTA ICT Research**. BECTA: Coventry, UK. Also available online at: www.becta.org.uk/page_documents/research/handhelds.pdf

SAVILL-SMITH, C., and KENT, P., 2003. **The use of palmtop computers for learning. A review of the literature.** Learning and Skills Development Agency: London.

In addition, Tony Vincent's 'Learning in hand' website is dedicated to the use of handheld computers in schools: http://www.learninginhand.com/ and features his own weblog.

Mobile devices in HE/FE

The Educause website is a good source of HE/FE material, although it is primarily American in focus: http://www.educause.edu/home/720

In the UK, a lot of work has been done at Wolverhampton's School of Computing and IT. Further details can be found at Brendan Riordan's Website: http://www.scit.wlv.ac.uk/~in6478/research.html
The University is also hosting the Second National Workshop and Tutorial on Handheld Computers in Universities and Colleges in 2005 (further details: http://www.e-innovationcentre.co.uk/events/120105/120105.htm)

Glasgow Caledonian is undertaking some work on supporting students on work placements through the use of mobile technologies. See Kathy Trinder's project at: http://elisu.gcal.ac.uk/flexiblemobile.html

Jon Trinder and colleagues at The Robert Clark Centre, Glasgow are undertaking the "Portable Assessment - Towards Ubiquitous Education" project. Further details from: http://www.ninelocks.com/ProjWeb/about.html

Birmingham University's Educational Technology Research Group has undertaken work in mobile technologies. A recent paper of note is Corlett, D., Sharples, M., Chan, T., Bull, S. (submitted) **Evaluation of a Mobile Learning Organiser for University Students**, Paper submitted to Journal of Computer Assisted Learning. Available online at: http://www.eee.bham.ac.uk/sharplem/Papers/JCALsubmitted.pdf
See also Mike Sharples's Website at: http://www.eee.bham.ac.uk/sharplem/manage.htm

The TechDis work has already been mentioned, but we list it here for your convenience. http://www.techdis.ac.uk/

The JISC TechLearn service published Ted Smith's report on PDAs in higher education in January 2003. The report contains descriptions and links to a number of US and UK projects that are using PDA technologies in educational settings. http://www.ts-consulting.co.uk/DownloadDocuments/PDAsinFurther&HigherEducation.doc

For a general discussion concerning the drivers for the uptake of ICT within higher education see Nick Hammond's (2003) paper **Learning technology in higher education in the UK: Trends, drivers and strategies** in M. van der Wende and M. van der Ven (eds), The use of ICT in Higher Education: A mirror of Europe. Lemma Publishers: Utrecht, pp. 109-122. Also available online at: http://ctiwebct.york.ac.uk/LTSNASP/staffpubsdetails.asp?id=59

The Open University conducted some work with Palm PDAs in 2001. The work was undertaken by Agnes Kukulska-Hulme and Jenny Waycott at the Institute of Educational Technology. Their report is:
J. Waycott and A. Kukulska-Hulme, **An Evaluation of the Use of Personal Digital Assistants for Reading Course Materials on H802: Final Report**, The Institute of Educational Technology, The Open University, Milton Keynes, CITE Report Series 9, December 2001. Further details available at:
http://iet.open.ac.uk/research/projects/project_details.cfm?project_detailsid=123

MOBIlearn is a European-led research and development project exploring context-sensitive approaches to informal, problem-based and workplace learning by using key advances in mobile technologies. The project, which is due to complete at the end of 2004, includes the development of a reference mobile learning architecture which will be trialled by a number of EU partners. Further details: http://www.mobilearn.org

The JISC e-learning Programme has recently commissioned an investigation into pedagogical aspects of mobile and wireless technologies in education through their E-learning and Innovation - the Use of Innovative Technologies and Models to Support E-learning initiative. Further details at: http://www.jisc.ac.uk/index.cfm?name=elearning_innovation

John Whalley, from Bishop Burton College, East Yorkshire, has used PDA technology for fieldwork on soil sampling. See JISC Inform 5 for details:
http://www.jisc.ac.uk/index.cfm?name=pub_inform5