The Handheld Classroom: Educational Implications of Mobile Computing

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Abstract

Advances in handheld computing technology have meant that Personal Digital Assistants (PDAs) are no longer simply electronic replacements for paper diaries, with current models capable of performing a wide range of functions. Such increased functionality has seen the rapid adoption of handhelds in the corporate sector, but it is perhaps in education that this technology may have the greatest impact.

Our paper explored the use of handheld computers in a variety of educational contexts. The first part of the paper provides an overview of some of the recent research that has been done in this area, and identifies several key projects. The second section looks at the educational issues raised by these projects, and argues that, as with any educational technology, careful consideration must be given to student needs before any hardware or software can be introduced. The paper concludes with a brief discussion of potential future uses of handhelds in the classroom, focusing particularly on the possibilities created by new wireless standards.

Keywords: Handhelds, PDA, education, technology

Introduction

Although still very much in the category of emerging technology, handheld computers are gradually making their presence felt across a variety of fields. Advances in technology have meant that these devices are no longer just electronic replacements for paper diaries; current models can perform a wide range of functions, from document processing to communications. Such increased functionality has seen the rapid adoption of handhelds in the corporate sector, and indeed despite the current decline in technology sales, many predict strong growth in the market for handheld computers in the near future (Brighthand, 2002).

The last twelve months has seen this growth accelerate, as competition between manufacturers and falling component costs continue to drive prices down. Whereas previously the high price of many of these devices meant that they were almost exclusively the realm of early adopters and IT professionals, the lower price of current models has worked to rapidly expand the technology's user base. In this respect, it can be argued that those in the education sector have more to gain than most, as the functionality offered by handheld computing is extremely commensurate with the educational environment. It will be the aim of this paper to explore the use of handheld computers in education, focusing specifically on the benefits and disadvantages of their use in a variety of educational contexts.

1) The Rise of the Handheld Computer

While many companies have developed small electronic organisers over the past two decades, the current generation of handheld computers can be traced most directly to the release of two specific devices: the Apple Newton Messagepad and the US Robotics Palm Pilot. The former was released in 1993 and gave users the ability to create and edit documents as well as carry personal information such as contacts and schedules on a device which measured 185 x 114 mm, and weighed just 400 grams (Luckie, 2002). The Palm device was released in 1996 and offered similar functionality in terms of its personal informational management (PIM) applications but did so in an even smaller package, weighing in at just 180 grams. Both devices provided input via handwriting recognition, allowing the user to enter text by writing directly on the device's screen.

In the time since the release of these devices, advances in several technologies have meant that while the functionality of these devices has continued to increase, the size and price of the hardware has rapidly decreased. This is evidenced by a simple comparison of device specifications: the original monochrome Palm Pilot of 1996 contained a Motorola processor running at 16 megahertz, 128 kilobytes of RAM and retailed at US$ 249 (Daniels, 1997). By comparison, one of Palm's latest devices, the Zire 71, contains a 144 megahertz processor, 14 megabytes of RAM and has a backlit high resolution screen displaying more than 58 000 colours, and does this for US$ 249 (Palm.com, 2003).

The increase in hardware specifications has allowed a corresponding increase in functionality, with current devices being capable of far more that the PIM applications for which they were originally designed. In addition to storing diary entries, memos and contact details, the latest generation of Palm handhelds can also create and edit documents in Microsoft Word, Excel and PowerPoint formats, send and receive email and, to a limited extent, browse the Worldwide Web. This increase in functionality has largely been due to work of third-party developers, who have continued to push the hardware to its limits, creating a software library of over 10 000 separate applications.

Increases in the sophistication of handheld computers can also be attributed to competition between manufacturers, and in particular to the entry of Microsoft into the handheld device market. Prior to this, Palm Computing completely dominated the market with over 75% of all devices sold running the Palm operating system. However, aggressive licensing by Microsoft has seen a variety of manufacturers including Compaq, Hewlett Packard, Casio, Dell, Toshiba and Acer release devices running Microsoft's "Pocket PC" operating system. The result of this has been a steady decline in the market share held by Palm-based devices, so that by the end of 2002 the 75% share had been reduced to 31.7% (Gartner, 2002).

At the same time, overall sales of handheld computers has continued to grow steadily, with 14.6 million devices sold worldwide in 2001 (IDC, 2002) compared to 3.9 million in 1998 (Miles, 1999). Analysts expect this to rise to 31.6 million by 2006 (IDC 2002), although such projections are notoriously difficult to make accurately. In any case, the fact remains that there is already a significant installed base of compact, versatile and relatively powerful handheld computers, the use of which is no longer the sole domain of corporate executives and IT professionals. As indicated by software sales, handhelds are being adopted by individuals in almost every profession that relies on the acquisition and retrieval of information, with this being most evident in fields such as medicine and sales.

2) Handhelds in Education: Current Projects

Not surprisingly, people involved in all levels of education have also begun adopting handheld computing technology, with both students and teachers using the devices for a variety of purposes. Indicative of the interest in the educational use of handheld computers is the sheer number of trials that are either underway, or have recently been completed. The following section provides a sample of some of the key projects that have been conducted in this area. The projects outlined below have been selected primarily because they illustrate the diversity of work currently underway, both in terms of their scope and their educational applications.

a) The Palm Education Pioneers (PEP) Program

The Palm Education Pioneers program represents perhaps the largest single study of handheld computers in education, and was based upon the distribution of 175 sets of Palm handhelds to primary and secondary schools across the United States. The project was administered and evaluated by the research firm SRI, and centred on a two-tier system of grants offered to researchers and educators. The first level of grants were Classroom Teacher Awards, and were designed to allow individual teachers and technology coordinators to experiment with using handheld computers in a variety of classroom situations. These grants were awarded on a competitive basis, with applicants submitting a detailed proposal that was then evaluated by a panel of independent reviewers. Running in tandem with this scheme were the PEP Research Hub Awards, which were granted to research institutions, school districts and departments of education that exhibited a commitment to the integration of handheld computers in the classroom (Palm Inc 2002, p. 2).

The Palm Education Pioneers program utilised a variety of research techniques, with the primary form of evaluation being teacher questionnaires, which were distributed to participating teachers at the end of each semester. This was supplemented by a series of monthly project self-evaluation reports, in which teachers outlined the progress of their own projects and offered feedback on the program as a whole. Students were also consulted as part of the evaluation process, both in the form of surveys and through face-to-face interviews with SRI researchers during site visits (Palm Inc. 2002, pp. 3-4).

Although acknowledging that the teachers involved in the study were already somewhat predisposed to using technology for education, the study found that an overwhelming majority (more than 90%) described the experience of using handhelds to be positive. Perhaps more importantly, teachers noted that the introduction of the devices resulted in noticeable improvements in several educational activities, from increased rates of homework completion to improved willingness to participate in group work. (Palm Inc. 2002).

b) The Pittsburgh Pebbles PDA Project (http://www-2.cs.cmu.edu/~pebbles/)

Beginning in 1997, the Pebbles (PDAs for Entry of Both Bytes and Locations from External Sources) project was initially run by Carnegie Mellon University's Human Computer Interaction Institute. The objective of the Pebbles program is to research the ways in which PDAs can be used in conjunction with conventional personal computers, in spaces such as offices, meeting rooms and classrooms. The research being undertaken into handheld computing's relationship with the classroom deals with the ways in which testing and note-taking can be enhanced through the students' handheld computer linkup with the instructor's personal computer. As such, primary research is concerned with how handheld computers can augment other 'fixed' computers, instead of how they can replace them. Thus the user is not mobile at the time of the usage of these devices, but rather is in a space where handhelds and PCs are both present. The project terms this "multimachine user interfaces", or MMUIs (Myers, 2001).

Several studies were carried out to explore the use of the devices in different educational activities, with one of the most interesting of these involving what was termed "instantaneous test taking". During the spring semesters of 2000 and 2001, 100 undergraduate students in a second-level chemistry class at Carnegie Mellon University were given Jornada handhelds donated by Hewlett-Packard. Instructors conducted instantaneous testing by asking multiple-choice questions and then generating bar graphs using the relayed answers from the students' handhelds. This type of testing enabled instructors to evaluate the level of student understanding during a lecture. A survey of 50 chemistry students found that this was a preferred method of communicating during class (Chen, Meyers & Yaron, 2000). As a result of this research, several new human-computer interface issues were uncovered, pertaining to group work, individual work and the way in which ways the devices themselves communicate.

The project received funding from a number of high profile sources, including the Defense Advanced Research Project Agency (DARPA), the National Science Foundation (NSF), Microsoft and General Motors. In addition, equipment for the project was donated by companies including Symbol Technologies, Hewlett-Packard, Lucent Technologies, Palm Computing, IBM, TDK and the Mitsubishi Electric Research Laboratory.

c) The Palm Professor Pilot Project (http://www.georgefox.edu/palmprof/index.html)

Funded with a US$ 10 000 grant from the Northwest Academic Computing Consortium, the Palm Professor Pilot Project aimed to identify how handheld computing can enhance teaching and learning through the instructional use of PDAs. The project was conducted between April 2001 and April 2002 at George Fox University in the United States, and involved 11 faculty members from various liberal art disciplines across the university. These faculty members used PDAs to strengthen their lectures and improve productivity of course administrative tasks.

The equipment provided was a Handspring Visor PDA, a Presenter-to-Go module and data/video projector. The Handspring Visor PDAs were used as they come with an

expansion slot for increased functionality and were relatively cheaper than Palm-branded devices. The Presenter-to-Go modules are manufactured by Margi Systems and plug into the expansion slot on a PDA, enabling users to connect their device directly into a digital projector or other VGA interface. This module includes an infrared remote control, allowing users to conduct a presentation from anywhere in the room. The data/video projector provided by Instructional Media Services was shared among the participating faculty members and if another was needed when this particular one was in use, more were provided.

Whereas many other university programs are researching PDA use in the classroom in their capacity as storage mediums and administrative tools, the Palm Professor program was more concerned with using PDAs, in conjunction with the modules, as presentation tools. While the final results of the project have yet to be published, it was envisioned that course grades would be used to determine whether or not students had benefited from the alternative presentation methods. Surveys of participating faculty members would also be used to gauge the perceived effectiveness of the devices as teaching tools.

d) Handheld Composing: Using PDAs to Re-Conceptualise Artistic Practice
(http://www.nwacc.org/grants/2001/Polishook.html)

This project differs from most in that rather than use handheld computers in subjects from the humanities or sciences, it used them to explore potential applications in music. The primary objective of the project was to illustrate how the curricular use of PDAs enhances teaching and learning in the field of music composition and how it can transform artistic practice. A secondary objective was to ascertain whether the use of handheld computing devices in the arts could foster creativity, innovation and invention, as well as if PDAs can be used as artistic mediums in themselves.

With US$ 10,000 in funding from the Northwest Academic Computing Consortium, the project focused on 12 undergraduate and graduate music composition students at Central Washington University. The first phase of the project occurred throughout the 2001 and 2002 academic year and involved equipping the students with handheld computers, software and Midi expansion modules. Software installed on the devices consisted of MP3 players, composition and notation programs, sound digitisers, and a Theremin simulator. The students used the PDAs to arrange compositions for, among others, soloists, percussion ensembles, mixed chamber groups, string quartets and electronic media.

The devices served several functions in the program. They allowed students to play parts or combinations of parts of a composition in order to instantly evaluate the artistic strengths of the score. They also acted as archivists, storing all compositions for future use. In addition to this, the handhelds allowed students to compose their scores in any environment they felt comfortable in, not requiring them to work with laboratory equipment and instruments that may inhibit their freedom or creativity.

Assessment of the project took the form of weekly evaluations and student end-of-term essays on their experiences with using the PDAs. At the end of the trial the coordinator of the program, Professor Mark Polishook, produced an assessment report detailing the study's findings. According to the report, most students involved in the program retained the PDAs for use in their composing, stating that the handheld device opened up possibilities in music composition that did not previously exist. Some also stated that it was a convenient way to compose and store composition thoughts when they might have only had access to pencil and paper, due to the portability of PDAs.

e) ArcStream Solutions in Medical Schools
(http://www.palm.com/education/studies/study36.html)

Apart from computing, medicine is perhaps the discipline that has benefited most from the advancement of handheld computing devices over the last decade, and thus it is not surprising to find that medical schools are strongly represented in terms of handheld education projects. In the ArcStream study, three medical schools employed ArcStream Solutions to develop specific applications for use on handhelds running the Palm operating system, beginning in September 2001. Harvard Medical School, Florida State University College of Medicine and SUNY Downstate Medical Centre all implemented mobile computing programs to assist in the instruction of medical studies. Each institute utilised handhelds and a range of applications for use in their medical courses. For the Harvard Medical School project, ArcStream Solutions were employed to develop a Palm OS platform-based mobile solution that facilitated communication between students and faculty, and that provided detailed course information. Florida State University College of Medicine employed ArcStream Solutions to develop a Clinical Data Collection System (CDCS) that allowed students to retrieve and edit patient reports. For SUNY Downstate Medical Centre, ArcStream Solutions developed the Portable Resource for Integrated Medical Education (PRIME), an application that allowed faculty to monitor student/patient encounters and to provide instant feedback.

All three participating universities reported distinct advantages in using handhelds for education, especially in terms of allowing students to access medical information quickly and easily. The universities also identified better communication between students and faculty as a key benefit of the trial program.

f) OWLS (Online Wireless Learning Solutions) (http://www.owls.ecu.edu/)

With over US$4.5 million in funding from the United States Department of Education, Ericsson Inc., Handspring Inc., and Audio Intelligence Inc., the Online Wireless Learning Solutions (OWLS) program represents one of the most extensive trials of handheld computers in education yet undertaken. The project is also one of the only examples of international cooperation in this area, involving 9 universities and nearly 900 students, and spanning 5 continents and 24 US states. Unlike most programs, the students involved in OWLS are mainly working professionals undertaking undergraduate degrees, or completing a Master's or Doctorate. Tests and surveys were conducted continuously throughout the program to gauge the effectiveness of the usage of handheld devices in various learning activities.

The primary aim of the project is to develop and implement a course delivery system for mobile professionals that will provide different avenues of learning, enabling anytime, anyplace study. This program is specifically aimed at those who desire a university education but due to geographical hindrances or time constraints are unable to attend university in the traditional manner. In practice, the aim is to provide location-independent learning that is not reliant on a wired Internet connection, and to develop courseware that addresses the needs of mobile professionals and increases their productivity and efficiency.

Complementing the main OWLS program is the Handsprings to Learning project (http://www.ecu.edu/handheld/), operated by East Carolina University. This project was established with a grant of US$ 924,437 from the Fund for the Improvement of Post Secondary Education, and was supplemented by hardware, software and technical support from companies such as Handspring , Audio Intelligence Corporation, Xircom, InnoGear, Blue Nomad, MARGI Systems, Cutting Edge Software and DataViz.

The East Carolina University project involved 75 students enrolled in 3 courses. These courses consisted of one on-campus course offered by the School of Education and two off-campus, web-based courses offered by the School of Industry and Technology. During the 2001 academic year, new courses to incorporate handheld computers were the Colour and Design course offered by the School of Art and a course in the Sports Medicine program offered by the Department of Health Education. In all these trials, the researchers were primarily concerned with exploring handheld devices not simply as tools for personal use, but also as wireless tools for faculty/course selection, training, technical support, hardware development and program assessment.

Both OWLS and its affiliated Handsprings to Learning program have reported significant benefits in using handheld computers in education. In the case of the former, pretests, posttests and surveys conducted throughout the length of the OWLS program found that there was no significant difference between OWLS courses and similar courses that were offered on-campus. Furthermore, it was found that students using PDAs in their coursework overwhelmingly advocated the use of the devices to obtain course content. The main benefit of OWLS was found to be the ability of universities to offer courses to those interested in more flexible and time-efficient delivery technologies.

Similarly, the Handsprings to Learning project found that the use of the devices resulted in a more intensive and interactive learning environment, leading to increased involvement and preparation from students. It was also believed that the general training and knowledge of handheld devices and wireless technology obtained through the program would aid students in a workplace environment.

g) Handheld Computers in the Tertiary Classroom

Funded by an AUD$ 5000 internal grant, Swinburne University's Handheld Computers in the Tertiary Classroom project sought to explore the use of handheld computers for teaching and administrative tasks in a higher education context. Unlike many of the projects discussed here, this project was aimed directly at teaching staff rather than students, and focused on the ways in which handhelds could be used to enhance existing teaching methods as well as generate new teaching activities. The project was carried out over one academic year, with the researcher experimenting with using the device (an Ipaq 3870) in a variety of different classroom and non-classroom environments.

In the case of the former, the device was used primarily as a data-capturing device, with class attendance and participation being logged for each individual student. The key advantage of this was that all student details and course information could be kept in the one place, with additional marks for assessments such as presentations being entered in real time. All this data could be accessed almost instantaneously, allowing the teacher to provide detailed information on the progress of individual students whenever the need arose.

The handheld was also used to enhance classroom presentations with the addition of mobile presentation software and hardware. This allowed the researcher to conduct full PowerPoint presentations in small classroom environments, whereas previously only overhead projector transparencies were available. The main advantage of this was that presentations designed for large lectures could easily be adapted to and transported to smaller venues, thus saving time in re-formatting while also improving the visual appeal of the presentation itself.

These findings closely mirror those from other studies, and suggest that there are certain key activities which handheld computers are especially well-suited to, regardless of educational environment. However, this study also found that academics working at tertiary level

arguably had even more to gain from handheld technology than their counterparts at other levels. The fact that these devices usually come equipped with at least some spreadsheet and word processing software provides academics with the ability to instantly access and edit research in-progress, regardless of time or location. This has the potential to be especially beneficial in terms of conference travel, where the academic can carry editable versions of key documents with them, without the bulk of a traditional laptop.

3) Research Issues

As the preceding overview clearly illustrates, there is a significant amount of research currently being conducted into the educational implications of handheld computers. However, while the body of research is growing rapidly, questions still remain about the validity of some of the studies currently being conducted.

The first, and perhaps most important issue concerns the actual research rationale for many of the projects; almost without exception the studies canvassed here assume that handheld computers will be beneficial in a classroom environment, while only touching upon the potential negative consequences. This is perhaps a function of the relative newness of the technology under examination, in that most of the studies discussed here are initial trials rather than the kind of longitudinal work that would reveal a more nuanced picture of how the technologies work in the classroom. In this respect, it could be argued that the time has come to move beyond the simplistic question of whether or not handhelds have a place in the classroom, and begin focusing on the more detailed questions concerning how this technology might affect teaching practice in the long term.

A second, and related, question concerns the methodologies employed in the various research projects in this area. In some cases, (such as the Handheld Composing project) the research was initiated and conducted by someone with significant experience in teaching practice, but little experience in conducting detailed qualitative and quantitative research in an educational environment. Again, the newness of the technology is a contributing factor here, but the fact remains that there needs to be much more systematic research in this area before valid conclusions can be made. In particular, there needs to be substantial pre and post-trial testing of participants to determine how the introduction of handhelds affects the educational experience. At the same time, researchers also need to determine the criteria by which the "benefits" of handhelds is to be assessed. Obviously, improved academic performance represents the baseline measure for an educational study, but as with all technologies there are a host of other factors that need to be taken into consideration. As noted above, several studies identified increased participation and efficiency in group work as one of the more positive outcomes of the introduction of handhelds, but such interpersonal benefits are difficult to quantify. Future work in this area will obviously have to feature a combination of qualitative and quantitative techniques, as well as sample sizes large enough to validate their findings.

The issue of sample size also raises another set of concerns regarding the current research: scalability and transferability. Many of the projects outlined in this paper were conducted with very small groups (often a single class), and it is possible that the results obtained for such a small, cohesive group may not be applicable to a much larger sample. Similarly, the results of a study conducted in one location may not be directly transferable to another, as education is a very context-dependant enterprise. The majority of research done in this area has been carried out in the United States, and as such is commensurate with an American educational context. However, different education systems have different curricula, and indeed promote

different learning styles, and the extent to which results obtained in one context can be transferred to another is still open to question.

The issue of transferability is common to most research involving educational technology, however there are some research issues which seem to be more specific to studies of handhelds in education. The most important of these is the sheer pace at which these devices are developing, and the corresponding danger of obsolescence, both of the devices and the research conducted using them. This is perhaps most graphically illustrated by the issue of wireless connectivity; apart from some limited work involving sharing data via infrared "beaming", few of the projects discussed in this paper explored how wireless transmission could be used in education, simply because wireless communication using handhelds was almost unheard of two years ago. By contrast, almost every handheld manufacturer now has wireless models, or models with the capacity to be made wireless with the addition of relatively inexpensive peripheral hardware. This is in keeping with the wider trend toward mobility in computing generally, as evidenced by the push by many processor manufacturers to promote wireless versions of their technology.

For the classroom, wireless connectivity presents some intriguing, as well as disturbing, possibilities. Using short-range wireless technology such as 802.11b (commonly referred to as WiFi), students could access internet-based data while seated at their desks, or indeed anywhere within a 100-metre radius of a wireless access point. The same technology could also be used by students to share stored information between themselves and their teachers. This has the potential to encourage group work between students, thereby circumventing the problem of isolation often associated with computer-based learning. Obviously, a potential for abuse also exists with this type of technology, with the access of inappropriate web material, and exchange of inappropriate data (such as examination answers) representing the most immediate concerns. As with any technology in the classroom, a strategy for monitoring of the use of wireless handhelds would be a prerequisite for their introduction.

Handheld devices, and in particular wireless handhelds are increasingly becoming a significant part of the corporate environment, and exposure to these technologies in the classroom arguably provides students with a competitive advantage for later life. However, while this technology is advancing rapidly, most of the research is still being conducted on earlier non-wireless devices, meaning that some of the most intriguing educational implications are still being left relatively unexplored.

Finally, a common feature of almost all the studies discussed in this paper was the heavy involvement of handheld manufacturers in the research process. While the prices of these devices continue to fall, they are still relatively expensive technology, and in many cases donations from device manufacturers have been the only way for researchers to conduct their trials. Such involvement has obvious advantages for the manufacturers: not only do they increase their status as good corporate citizens by donating equipment to a worthwhile project, they also introduce themselves and their technology to a large number of potential customers. Such a close relationship between researchers and hardware manufacturers obviously raises issues in terms of scholarly independence, and while some manufacturer participation is certainly beneficial, research conducted using more independent resources is desirable.

4) Educational Issues

The role of technology in education has received an enormous amount of attention over the past decade, resulting in a large and rapidly expanding body of literature. Much of this work

has been devoted to examining the impact of technology on students and teachers, focusing on both pedagogical and practical considerations. In this respect, there are perhaps three main issues that have consistently dominated discussion in this area, all of which have important ramifications for the use of handheld computers in the classroom.

The first, and arguably the most important issue concerns equitable access. Most generally agree that access to technology resources should be provided to all students, and this access should be equitable, without any distinctions or restrictions placed on the users. As Eck et. al. (1999) explain, equitable access is a multi-faceted issue, with gender bias, gender gap, funding issues and choices on hardware, software, infrastructure and support all needing to be considered by the institution introducing the technology. In addition to these basic factors, institutions must also be conscious of accessibility issues in terms of social, economic or educational status, and hearing, visual, mobility and learning disabilities (Eck et. al., 1999), all of which can have a profound impact on the implementation of any educational technology. Parr (1995) takes the issue farther, raising the question of whether a school should "aim for equality of access, or is the consideration equity in terms of outcomes, a goal which suggests that those most in need receive the most?"

It can also be argued that these considerations are even more crucial in terms of handheld computers. While most technologies are designed to be used in group contexts, handheld computers are very much personal devices, and as such are not easily categorised as a shared resource. This is especially true in terms of the physical size of the devices themselves, with the small size and pen-based input method meaning that only one operator can effectively use them at a time. In this respect the introduction of this technology into the classroom may create an educational "digital divide", where some students attain an advantage through their access to handheld computing. Every one of the studies discussed above involved distributing the devices to a select group of students, meaning that any benefits derived from the technology's use were not shared equally. Admittedly, as all the studies were trial projects it is unfair to expect equity to have been high on their list of priority, but the fact remains that such issues would have to be taken into account should a more wide-scale implementation of handheld computers proceed. While these devices are not as expensive as other computing technologies, there would be few educational institutions which could afford to equip all their students with handheld computers, meaning that issues of equity will certainly arise.

Secondly, professional development represents the primary means of supporting equitable access, and needs to be given as much attention by institutions as the technology they choose to install. As Spratt, Palmer and Caldwell, (2000) explain, professional development plays a crucial role in the introduction of educational technologies, both in terms of the practical familiarisation with the technology as well as accelerating the broader cultural change required to make the implementation a success. Many of the projects discussed above were instigated by individual staff members who had an interest in exploring the educational possibilities of handheld computers. In these cases professional development was very minimal, with the staff members themselves utilising their existing knowledge of the technology to design the implementation program. Typical of this scenario was the Handheld Composing project conducted at Central Washington University, in which the chief researcher provided both the educational input as well as the technical support. In other cases, such as the Palm Professor Pilot Project, staff members with expertise in the use of handhelds were used to train other project participants, with minor technical support coming from equipment vendors. Even the Palm Education Pioneers program, which represents the most extensive and systematic study yet conducted, seemed to offer very little in terms of

providing assistance in staff development for the participating educators. While the project's administrators did keep in regular contact with the participants, this primarily took the form of project evaluations rather than ongoing support.

Clearly, teachers and instructors need to be highly proficient in the use of the technology for students to receive the most beneficial instruction. It is integral that teachers and instructors be provided with an ongoing professional development program that caters not only for training but also for fostering a supportive and motivated outlook towards using technology. One-off training sessions and workshops tend to be inadequate for this purpose, and can sometime lead to the failure of the project as a whole. Professional development programs should contain connections to student learning and curriculum specific applications, hands-on technology use and active participation, a variety of collegial learning experiences, sufficient time for teachers to further develop their skills, technical assistance and administrative support, adequate resources and continuous funding (Rodriguez & Knuth, 2000). Furthermore, a strong network of technical support within the institution is another requirement for effective professional development. A technical coordinator suits this purpose, and technical support staff and personnel should be employed to maintain equipment.

In addition to this, Kincaid and Feldner (2002) argue that for any technology to be successfully integrated into an educational institution, it is necessary for there to be a strong leadership stance taken by administrators. According to the authors, recent research indicates that principal leadership represents one of the most important factors affecting the effective use of technology in classrooms. For this reason any program which seeks to introduce handhelds into a classroom context is more likely to succeed if those in administrative positions are first familiarised with the technology. Furthermore, Kincaid and Feldner note that the speed of acceptance of new technology is greatly enhanced when this administrator leadership is paired with a mentoring programme, in which staff with some technological expertise provide guidance to their less experienced colleagues. As noted above, this type of peer-to-peer training was already a feature of many handheld education projects, although it is usually conducted on a very ad-hoc basis.

Finally, while ensuring the proficiency of educators in managing technology represents a key component of any implementation program, successful technology integration usually only occurs when students remain the primary focus. As Epper and Bates (2001) argue, the most successful examples of technology adoption have occurred in environments where teaching and learning objectives have been the driving force. Computers and other technology can be more alluring to students, but educators must be aware that this allure is not the only requisite for the successful integration of technology into the classroom. Technology should also not be used as stand-alone in a classroom setting, but rather it should be incorporated as part of the curriculum alongside more traditional methods of instruction. In this respect, it is important that the technology should not simply be imposed on teaching staff, and that teachers have the opportunity to shape the way technology is integrated into their practice. This point is lucidly made by McNamara, who argues that teachers are in the best position to identify appropriate areas for technological integration:

The classroom teacher is in the unique position of being able to control and/or manipulate many of these factors. It is the teacher who determines the role of technology (educational) in the classroom and thus, directly or indirectly, its effectiveness. Even in an individualised situation much of the responsibility for the ultimate success of the instruction lies with the teacher, in terms of selection of appropriate media, hardware, materials and in the organisation of the instructional situation. (McNamara, 1985).

McNamara's point is especially relevant in relation to handhelds, in that unlike established technologies such as desktops and laptops, handhelds may require significant amounts of training if students are to utilise them to their fullest extent. Handhelds usually require users to learn a modified alphabet for imputing data into the device, and in many cases this impedes effective use. Indicative of this was the fact that 40% of those participating in the Palm Education Pioneers program reported that they experienced some difficulty in learning the device's input script.

More generally, teachers are also in the best position to determine to which specific subject areas handheld technologies are suited. The projects discussed above illustrate that this technology can be applied to a wide variety of different subjects ranging from social studies through to music, but this is not to say that that handhelds are able to enhance learning in all activities. For this reason it is important that teachers be involved not just in the implementation phase of a handheld project but also in the planning stage, so they their input may be sought in terms of curriculum design. This was not necessarily an issue for many of the projects discussed in this paper, as many were initiated by people already familiar with the technology and how it might be applied to an educational environment. However, in situations where participating teachers have had little or no experience in dealing with handhelds, some pre-project exposure and training is likely to be required.

5) Conclusion

As is the case with all emerging technologies, the future development of handheld computers is still very much uncertain, and will depend on the interaction of a wide range of social, technical and economic factors. However, what is clear at this time is that many within the education community see significant potential for the use of these devices in a classroom environment. The sheer number of projects currently underway or recently completed is indicative of this, and also illustrates the wide variety of educational contexts in which these devices can be used.

The existing projects also strongly demonstrate that the successful implementation of handhelds requires a solid understanding of contemporary educational procedures, and more importantly, requirements. In almost every project reviewed for this paper, handheld technology was used to facilitate activities that were already part of the institutions' curriculum, rather than to support activities specifically designed to centre on the technology. The significance of this cannot be understated; the introduction of handheld computers (or indeed any technology) must be in response to a clear educational imperative. While new technologies can offer new and creative modes of learning, the primary educational goals remain the same: to equip students with a set of skills and knowledges that will help prepare them for later life.

Almost paradoxically, it is this broadest educational goal that is most clearly served by the use of handheld computers. Many of the studies canvassed for this paper noted that the very act of exposing students to emerging technology such as handheld computers could be seen as a positive in itself, in that it was felt that such exposure helped prepare them for the technology-centred work environment they would soon be entering. Teachers involved in the Palm Education Pioneers program in particular saw this as an important benefit of the project, with over 70% of the teachers involved seeing increased technological proficiency as being a major benefit (Palm Inc. 2002, p. 13).

In many ways the projects canvassed for this paper represented the cutting edge of educational technology, but it is important to remember that technology is advancing so

quickly that many of the techniques and strategies employed in these projects already seem dated. Although most of the projects discussed here are less than two years old, handheld technology has already moved well beyond what the devices used in these studies were capable. In the last year alone, the processor speed and memory capacity of the most popular handhelds has doubled, and in some cases quadrupled, dramatically expanding the capabilities of the hardware. At the same time, the software library for the two main operating systems has also grown substantially, both generally and in terms of education-specific applications.

The rapid advance of these technologies also has a potentially dangerous flipside, in that there still exists a real possibility that the devices discussed in this paper may evolve out of existence. Several manufacturers have already begun moving away from the stand-alone handheld and have incorporated mobile phone functions into their devices, while many mobile phone manufacturers have begun including PDA functionality in theirs. At the same time, manufacturers of traditional laptops have begun experimenting with the size and design of their products, with the latest innovation being the release of several tablet-style units which combine traditional laptop and PDA features, albeit at relatively high price-point. For this reason, future research into this area must remain flexible enough to deal with technological developments.

Handheld computers obviously present many benefits from an educational perspective, but it is clear that much more work is needed in this area to determine optimal strategies for their implementation. Specifically, there now has to be a concerted effort to explore the potential of these technologies in a variety of educational contexts, encompassing a range of curricula, disciplines and learning styles. Most importantly, this work needs to be co-ordinated so that the results of these studies can be shared between researchers. This is indeed a substantial undertaking, and it is hoped that the overview of existing work provided in this paper may perhaps serve as a starting point for such an endeavour.

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