Pers Ubiquit Comput (2003) 7: 30–43
DOI 10.1007/s00779-002-0211-x

ORIGINAL ARTICLE

J. Waycott · A. Kukulska-Hulme

Students' experiences with PDAs for reading course materials

Received: 1 March 2002 / Accepted: 24 August 2002
© Springer-Verlag London Limited 2003

Abstract The availability of text reading and editing software for Personal Digital Assistants (PDAs) makes it timely to consider whether PDAs are useful tools for reading learning materials. This paper describes a study that evaluated the use of PDAs for reading by students on a Masters course run by the UK Open University. The evaluation consisted of pre- and post-questionnaires, and follow-up interviews. In addition, students discussed their experiences in a computer-based conference. Findings show that while the portability of the device was welcomed by students, and the electronic format was advantageous, limitations such as the small screen size, navigation difficulties, and slow and error-prone methods for entering text, made it difficult to read and interact with documents on the PDA. The paper recommends that further research consider the value of PDAs as reading devices in the context of other potential ways that PDAs can be used as learning tools.

Keywords Evaluation · Handheld computer · Learning · Palmtop · PDA · Reading

1 Introduction

1.1 Palmtop computers as learning tools

Palmtop computers, also known as Personal Digital Assistants (PDAs), are highly portable and personal computing appliances, which can be carried around and used 'anytime, anywhere'. They can be used for a variety of functions; for example, to manage work or study schedules, to record and store data, and to access and disseminate information. In addition, the availability of e-book reading and editing software for most PDAs means they can also be used to read and interact with electronic text. As Stonier [1] predicted in 1991, people can now use handheld computers as electronic books. Recently, this increasing functionality of palmtop computers has led several authors to argue that palmtop computers could be usefully exploited as learning tools [2–7].

Studies investigating the potential use of palmtop computers as learning tools have primarily been conducted within school settings [4,8,9], although recent projects in the United States have also begun exploring the use of such devices in college and university settings [10,11]. Fung et al. [2] speak of a 'paradigm shift' towards portable computing in education, likening it to the historic shift from reading as an activity that took place only in centres of learning to an activity that became an integral part of everyday life. There is great potential for palmtop computers to provide students with a tool that can support learning in various contexts. Palmtop computers can be used, for example, in field work to record and share data, in libraries and museums, and at home, as well as in the classroom [3].

Sharples [6] proposes that palmtop computers could also be useful lifelong learning tools. He suggests that such tools could accompany learners throughout their lives, and be used to input data and access information whenever the learner feels it is necessary. In this way, portable devices would become lifelong learning tools that release the learner from situational constraints imposed by desktop computers. Similarly, portable computing technologies could be valuable for supporting open and distance education. Distance education students typically have to fit their self-managed learning activities around other tasks, such as work and family commitments [12]. Providing access to learning resources anytime and anywhere, palmtop computers could enable students to make more effective use of time while away from the home or office environment.

J. Waycott (✉) · A. Kukulska-Hulme (✉)
Institute of Educational Technology,
The Open University, Walton Hall,
Milton Keynes MK7 6AA, UK
e-mail: J.L.Waycott@open.ac.uk
e-mail: A.M.Kukulska-Hulme@open.ac.uk

1.2 Using electronic text

The use of electronic text on desktop and laptop computers is not new. With the advancement and proliferation of information technologies, including such resources as the Internet and online books, reading is no longer confined to the use of printed text. Using a computer as a medium for reading text can offer advantages such as efficient search strategies, hyperlinks that connect sections of text, and convenient storage of large amounts of information [13–15]. However, people generally prefer reading paper documents to reading text on a computer screen [14,16,17]. In a study that compared the two media, O'Hara and Sellen [16] found that paper offered several advantages over computers. Participants in the study were assigned to either an 'online' condition or a 'paper' condition. Both groups were asked to read and summarise a 4-page (A4) article. Those in the paper condition were given a printed copy of the article and pen and paper for note-taking and summarisation. Those in the online condition were asked to read the document, take notes, and summarise the paper on Microsoft Word. Therefore, participants used either paper or the computer for all reading, note-taking and summarising tasks. Those is in the paper condition were able to navigate efficiently through the document using their knowledge of the information space and familiarity with the page layout to flick through the pages, jumping easily from one section to another. They were able to do this while simultaneously recording notes on a separate piece of paper. Meanwhile, those using the electronic version found it cumbersome to switch between viewing the document and taking notes, and they were only able to perform these activities serially, rather than simultaneously. These results suggest that using electronic text to read and take notes may be awkward compared with the relative ease of using paper documents.

Other common arguments for the superiority of paper are that paper can be used anywhere, compared with desktop computers that are static and can only be used in an office or desktop environment [14]. Laptops, too, are insufficiently portable, as they cannot be used in the same manner as books. With books, readers can sit anywhere, start reading immediately, change reading positions, and move easily from place to place. In contrast, desktop and laptop computers have many ergonomic constraints, with readers having limited control over the comfort of their reading environment [18]. The portability issue, however, may no longer be relevant, given the increasing availability of handheld e-book devices and the addition of 'document-reader' software on palmtop computers such as PDAs [13,19]. Such technologies aim to offer readers the benefits of accessing text electronically (e.g. storing several books on one device) while limiting the difficulties of reading text on a desktop computer. Researchers in this field argue that for such developments to be accepted and successfully integrated into workplace and learning cultures, they need to be designed to support the ways people actually read and use text [20,21].

1.3 E-books and PDAs

E-book devices are dedicated appliances designed specifically for reading electronic text [18]. Research investigating reading behaviours has produced several recommendations for the design of e-book readers. Such research recommends that e-books enable the recording of notes and annotations, offer facilities for searching, navigating and bookmarking, and support flexible and portable use of reading materials [20–23]. Thus, e-book readers are designed to fit in with the existing activity of reading and to support strategies that readers would typically use when interacting with printed text. However, dedicated e-book readers are designed for one task only (i.e. reading); therefore, in an educational context, students who wished to use an e-book reader would be required to purchase a piece of equipment that would only serve one purpose. This may be unrealistic for many students on limited budgets.

It may be, though, that students would use a tool they already owned to read electronic text while on the move. Personal Digital Assistants are general tools, designed initially to support personal information management [24]. They offer features such as a diary, address book and note-taking facilities. It may be that some students in distance education, particularly in disciplines such as business and educational technology, already use a PDA to support their workplace activities. E-book reading software is now widely available for use on PDAs [19]. Therefore, it is timely to consider the benefits and limitations of using PDAs to read study-related texts, and to determine what impact the use of a PDA has upon the activity of reading course materials.

1.4 Possibilities and constraints

The introduction of a new tool into an existing activity, such as reading, will inevitably disrupt and change that activity in some way. Carroll and colleagues refer to this process as the 'task-artefact cycle' whereby "an artifact suggests possibilities and introduces constraints that often radically redefine the task for which the artifact was originally developed." [25, p79]. Thus, the task of reading would be redefined through the possibilities and constraints imposed by a PDA. The primary possibility introduced by a PDA is, of course, portability and, consequently, the ability to have easy access to information stored electronically. The constraints are equally apparent: the portability and palmtop size of the PDA compromise other features such as screen size and text input mechanisms, which may limit the extent to which the tool could be usefully applied in a learning context.

Development of the original PalmPilot involved careful consideration of every pixel used on the interface

so that more screen space could be available for viewing information [24]. However, making text and headings small in order to fit in more information could be counterproductive. Early user testing of Windows CE – the operating system used on several PDAs – suggested that when a font size is below 10, reading becomes difficult and inaccurate [26]. Software can give users control over the font size; however, increasing the font size inevitably decreases the amount of information that can be viewed on the screen at any time. As Dillon [14] argues, a small screen isolates the text on display, removing it from its context and making it difficult for readers to scan-read back and forth several lines of text.

A further constraint of using a PDA for reading is that it may be difficult to take notes on the same device. PDAs do not benefit from the same data input capabilities as desktop and laptop computers, which typically have a full size keyboard and mouse. Most PDAs and similar devices have touch-sensitive screens that enable direct manipulation of the onscreen interface through the touch of a stylus or finger. While such an interface is useful for quickly accessing and viewing applications [24], it is not so beneficial for entering text. Typically, users would enter text on a PDA using a small on-screen keyboard or by writing on the screen in a special handwriting script, which the PDA then converts into type. Handwriting recognition systems, however, lack in speed and accuracy, and data input methods on PDAs are generally considered problematic [27,28]. Thus the advantages of electronic notes (which can be shared, searched, incorporated into assignments, and so on) are counterbalanced by the awkwardness of current input methods. Given that PDAs, along with e-book reading software, are becoming more widely available, it is important to consider what implications the possibilities and constraints introduced by these tools would have upon the activity of reading for learning purposes.

2 The evaluation study

2.1 The course and participants of the study

An evaluation study was undertaken to understand the changes that occur when students use a PDA to read and interact with course materials. The study centred on the UK Open University course 'H802: Applications of Information Technology in Open and Distance Education.' The course is primarily delivered online, making use of web resources and FirstClass conferencing software. The final block of the course (the last two months), however, uses print-based reading materials, and it was during this block that the study was conducted, from August to the end of September 2001.

The course is one of three that make up a Masters programme in open and distance education. In many ways, this course is not a typical Open University course. The subject matter involves evaluating the use of computer technologies to support distance education. Therefore, students are encouraged to critique and evaluate their own experiences of using information technology while undertaking the course. For this reason, the course offered a valuable forum in which to conduct this study. Students were generally eager to try out a new medium for reading course materials and offered extensive feedback on their experience of using the PDA for reading. All 65 students enrolled in the course were supplied with PDAs towards the end of July 2001. However, it should be stressed that participation in the evaluation of PDAs was voluntary.

The course is delivered globally and so students are geographically dispersed and come from various cultural backgrounds. The course is undertaken part-time; therefore most students are also involved in various other professional activities. Participants were primarily novice PDA users, although there were some who had used palmtop computers in the past and some who currently owned a PDA or similar device.

2.2 Aims of the evaluation study

The evaluation of students' use of PDAs for reading course materials aimed to assess the possibilities and constraints introduced by the new tool, and to examine how this new tool impacts upon students' reading strategies. The investigation therefore centred on the following questions:

- What are the benefits of using PDAs to read course materials?
- What are the limitations of using PDAs to read course materials?
- How does the use of PDAs change the way students read and interact with course materials?

The following sections describe how the evaluation study was conducted and present the results that were obtained from it. The findings are then discussed with reference to the above questions.

3 Method

This section outlines the equipment used in the study, including the PDAs and software given to students, and describes the methods used to collect and analyse the data.

3.1 Equipment

3.1.1 PDAs

Students were supplied with Palm m105 PDAs. The Palm m105 was chosen because it is a relatively affordable model that offers all of the features common to PDAs, such as note-taking facilities, an address book, calendar and to-do list, as well as the options for

additional features such as email and Internet access. The m105 has 8mb of Random Access Memory, which is sufficient for storing a large amount of electronic text. Palm PDAs are widely available and there is a variety of third party software that can be used with this platform, enabling students to explore the potential uses of PDAs beyond reading course materials.

The Palm m105 has a touch-sensitive screen and screen icons are manipulated by using a pen stylus or finger to tap on the screen. Text can be entered by tapping letters on an onscreen keyboard, or by using the Graffiti handwriting recognition software. This involves learning the specific Graffiti alphabet characters and writing these on the screen with the stylus. The computer then converts the handwriting to type.

The size of the Palm m105 is 11.8 × 7.9 cm and it weighs 125 g with batteries installed. The screen display area is 5 × 5 cm. It operates on two AAA batteries which should last for up to two months. It has a monochrome display, with black writing on a green background. There is also a backlight, so the display can be viewed in the dark.

3.1.2 Document reader software

WordSmith, a commercially available document editor and viewer, was used to present course materials on the PDA. This was chosen because it is a flexible program that can be used for a variety of purposes, including to record notes, edit documents, and read text. The document viewer mode enables users to read the text in a variety of ways, for example, by using the scroll bar on the side of the screen or the buttons at the bottom of the device, by dragging the stylus along the screen, or by using the 'teleprompter' facility which moves the text automatically, one line at a time. In addition, the software has search facilities, such as 'Find' which seeks out instances of the specified word, and 'Go to paragraph' which allows users to jump to a particular paragraph.

The software was supplied to students on a CD-ROM. Students transferred the contents of the CD-ROM to their desktop computers, then downloaded the software onto the PDA, using a standard cable supplied with the PDA which connected to students' desktop or laptop computers.

3.1.3 Course materials

Three sections of the course materials (67 A4 pages) were provided for access through the PDA. These sections made up nearly half of the Study Guide for the final block, and were written by academics associated with the course. The Study Guide is a discursive guide to the readings for the block, with in-text activities. In the 2001 presentation of the course, it was supplied on A4 size paper in a ring-bound folder. During the study, students had access to both the printed version of the course materials and the electronic version. Use of the PDA to read course materials was voluntary.

The electronic version of the course materials was supplied in Word Document format on a CD-ROM. The documents were not reformatted for presentation on the PDA. It should also be pointed out that the materials supplied were entirely text-based, as the document reader software did not support presentation of graphical displays or images. Students copied the documents to their desktop computers and then downloaded them onto the PDA. The course materials could then be viewed on the PDA using the WordSmith software. Figure 1 shows how the course materials looked on the PDA.

Participants received the manufacturer manuals that were supplied with the Palm m105 PDA, as well as an online manual for the WordSmith program. In addition, they were provided with further instructions about how to install the software and hints about using the PDA for reading course materials. These included tips such as how to highlight the text by making it bold or underlining it, how to write notes, and how to operate the different document viewer modes.

3.2 Data collection

3.2.1 Questionnaires

Pre-questionnaires were administered before students received the PDAs. The purpose of conducting a pre-questionnaire was to determine students' preconceptions about the potential usefulness of PDAs as learning tools, to ascertain the extent of students' past experience of using PDAs, and to find out the sort of strategies they used when reading paper and computer-based materials. Open-ended questions asked students to specify how

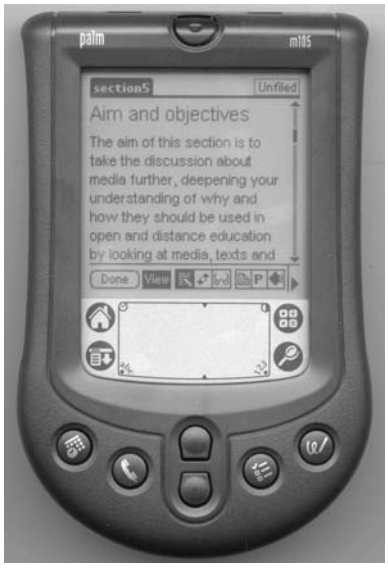

Fig. 1 A screen shot of the course materials on the Palm m105 PDA

they believed the PDAs would or would not be useful to them.

Post-questionnaires were administered at the end of the course, three months after the pre-questionnaires. The questions asked students what features of the PDA they had used, whether they had found the PDA to be a useful tool for supporting their studies, what sort of reading strategies they adopted when using the PDA, and what the benefits and limitations were of using the PDA to read course materials. Both pre- and post-questionnaires were administered electronically via a website and consisted of a mix of closed and open-ended questions.

It was not compulsory for students to respond to each questionnaire, and both questionnaires were distributed to the entire cohort of students. Consequently, not all students who responded to the pre-questionnaire also responded to the post-questionnaire, and some who responded to the post-questionnaire had not filled in the pre-questionnaire. This made it difficult to compare the two sets of responses.

3.2.2 Interviews

Interviews were conducted by telephone with 10 students, randomly selected from the entire cohort of students. Only a small sample of students could be interviewed due to time constraints. Nevertheless, the interviews elicited in-depth information about how the use of the PDA changed students' reading strategies, as well as gaining further understanding about the issues that impacted upon students' use of the PDAs.

3.2.3 Computer conference

Students also participated in a computer-based discussion conference. Discussion conferences are a core element of the course, and therefore students were familiar with using the FirstClass conferencing software and were comfortable sharing information and experiences with other students through the conference. Twenty-seven students contributed to the conference discussion on PDAs. Of those, six students were particularly active in the discussions and were responsible for 47% of the messages between them. This group of active conference participants consisted of three students who already owned and used a PDA and three students who were novice users.

In the conference, students shared their experiences of using the PDAs to read course materials, offered each other advice about software and features to try, and helped each other with any technical difficulties they experienced. The computer conference therefore provided a useful means of capturing data about how some students used the PDAs. The discussions were not mediated or directed by tutors or evaluators. Researchers participated in the conference only to answer specific queries or to make announcements about the study.

3.3 Data analysis

Questionnaire responses were collated in an Excel spreadsheet. Responses to closed questions were graphed and percentages were used to identify the spread of responses. It was not deemed necessary to do statistical analyses, given that we were not comparing groups or testing hypotheses.

Open-ended questionnaire responses and interview transcripts were examined to ascertain students' perceptions of the benefits and limitations of using PDAs for reading, and categorised accordingly. As described in Sect. 4.2, the most common limitations included small screen size, navigation difficulties, awkwardness of entering text, and the benefits included portability and the advantages of electronic text. Interview and questionnaire comments, and contributions to the online discussion conference, were also examined to determine how the PDA impacted upon students' reading strategies. Comments relevant to this issue were used to elaborate on evidence from the closed questionnaire questions which showed how note-taking and marking up text when using the PDA compared with the same strategies used when reading paper (see Sect. 4.3).

4 Results

This section reports the results obtained by all the above means of data collection. Students' opinions about the benefits and limitations of using PDAs for reading course materials are reported, as are the strategies that students used when reading paper and computer-based materials, and the impact that the PDA had upon these strategies.

Comments from the interviews and online conference discussions provide illustration and further clarification of the issues that emerged from the questionnaire responses. In addition, data from these sources reveal further uses that students made, and hoped to make, of the PDA as a learning tool.

4.1 Expectations about PDAs

Forty-four students responded to the pre-questionnaire. Of those, nine said that they had used a PDA in the past. Students were asked to indicate how useful they believed the PDA would be for reading course materials. Most respondents (29) said they believed the PDA would be somewhat useful. Five students believed the PDA would be very useful, and nine said they felt it would be not at all useful. Students who had previously used a PDA had mixed expectations about their potential usefulness for reading course texts. Two previous users said the PDA would be very useful, six said the PDA would be somewhat useful, and one previous user said the PDA would not be useful for reading course texts. This respondent gave the following reason for that expectation:

> "I have not tried it yet, but think the screen size will be too small. This will make scan reading really difficult. But anything that reduces the amount of stuff I carry around when I am commuting would be worth a go."

This comment was not atypical. Thus, it appears that students had mixed expectations about how useful the PDA would be for reading course materials. They were concerned about possible limitations, such as the small screen size and potential difficulties highlighting text on the PDA. However, they were also positive about anticipated benefits, such as being able to carry course materials around on a portable device, and being able to take notes in electronic format.

4.1.1 Expected limitations

Small screen size. The primary limitation that students anticipated was that the PDA screen would be too small and difficult to read from. This is unsurprising, given that small screen size is one of the general limitations of palmtop devices that may off-set the advantages of having a lightweight, portable device. Students expected the text to be small and were concerned about problems of eyestrain. Past experience of reading text from a computer screen also contributed to expectations of difficulties:

> "I have trouble reading material off a screen in any case and cannot see how something with such a small screen will enable me to read large amounts of text with ease."

Navigation. Students were also concerned that insufficient clues about the information space of the reading material would make it difficult to find information quickly and browse through the text, as they would when they use a familiar paper-based document:

> "I frequently know exactly where to find something I've read and want to return to, because I can picture in my head exactly where it is on the page. I won't be able to do that with scrolling text. The tactile qualities associated with book reading are essential."

Highlighting and annotating text. Another anticipated limitation was the potential difficulty of highlighting and annotating text on the PDA, as compared with highlighting and annotating text on paper. Students were concerned that such reading (interaction) strategies would be difficult to undertake when using the PDA to read course materials.

4.1.2 Expected benefits

Portability/Mobility. The most common potential advantage identified was that the PDA would make it easier for students to carry around reading materials whilst on the move. The issue of portability was considered important to students on this course, many of whom had to travel frequently for work purposes. Students found the paper-based course materials to be heavy and cumbersome, and so the anticipation of being able to carry the documents in a portable lightweight device was appealing.

Recording notes. Students also saw potential benefits in using the PDA to record and store notes electronically. They felt that having a portable device which could be used to record electronic notes would support their learning activities, enabling them to summarise course materials more effectively and keep their notes better organised.

4.2 Evaluation of the PDA as a tool for reading course texts

4.2.1 Usefulness

Thirty-five students responded to the post-questionnaire. When asked how useful they found the PDA for reading course materials, eleven students (31%) said they found it not useful, fifteen students (43%) found it somewhat useful and six students (17%) found it very useful, as shown in Fig. 2. Three students did not answer this question. Students were also asked how useful the PDA was overall, that is, for general tasks in addition to reading course materials. In response to this question, seven students (20%) said they found the PDA to be not useful, 13 (37%) said it was somewhat useful and 14 (40%) said it was very useful. One student did not answer this question. When using the PDA as a general tool, students utilised functions such as the diary (18 students), address book (21 students), to-do list (19 students), notes or memo pad (24 students) and calculator (13 students). Therefore, the PDA was a useful time and information management tool and some students took advantage of these facilities.

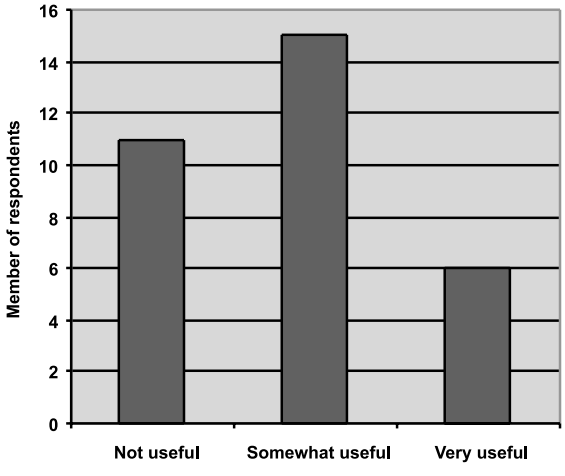

Fig. 2 Perceived usefulness of PDAs for reading course materials, as determined by post-questionnaire responses

4.2.2 Ease of use of PDA

Students were asked to indicate how easy or difficult they found it to read course materials on the PDA. Thirty-one students answered this question, and the majority of respondents (68%) said they found it either very difficult (eight students) or somewhat difficult (13 students). Six students said it was 'neither easy nor difficult', one student said it was rather easy and two students said it was very easy.

Students were asked why they felt it was easy or difficult to read course materials on the PDA. Reasons given included difficulties reading from a small screen with small text size, the awkwardness of having to scroll through the text, difficulties skim-reading and navigating through the text, and the inability to annotate and highlight text in the same way as one would annotate or highlight text on paper. These issues are elaborated further in the following sections.

4.2.3 Limitations of using the PDA for reading

Responses to the open-ended questions in the post-questionnaire, as well as comments made in the interviews and online discussion conference, revealed that, as they had anticipated, students did experience constraints when using the PDA for reading course materials. The main limitations identified were the small screen size of the PDA, navigation difficulties, and the awkwardness of entering text on the PDA.

Small screen size. The small screen size of the device was considered a severe limitation. Only a small amount of text could be viewed at any one time and this meant students found it difficult to scan through the text and gain an overview of the document. Reading text on the small screen was slower than on paper, and students had to concentrate on each individual line of text. Students found that they had to change their reading strategies in order to allow for the small screen size:

> "Only being able to see a small amount of text at any one time, you have to adopt a different reading strategy. With text on paper I can scan read some way ahead – this is not possible with the m105."
>
> "Reading is not a linear process confined to decoding the individual words in sequence – you need to be able to refer quickly to other parts of a text, gain an overview of the organisation, etc., all of which is impossible on a screen this size."

In addition, students found the screen quality on the PDA to be poor, with insufficient contrast and the limited colour scheme making it difficult to differentiate between sections of the text.

Navigation difficulties. Navigating through documents was difficult on the PDA, and students compared it unfavourably with flicking back and forth between pages in a paper document. Some students found visual clues, such as headings, difficult to see on the small screen of the PDA, and this contributed to navigational difficulties:

> "(It was) more difficult to navigate around the text ... I mean, obviously I'm comparing it with hard copy ... It's just that, scrolling through the screens it's difficult to pick up headings and things like that."

Students found the software's navigational tools, such as the 'Find' and 'Go to paragraph' features, to be "irksome." One interviewee suggested navigation may have been easier if there had been hyperlinks between sections of the document:

> "I did find it difficult, because you have all the headings at the beginning, which is very good, but they're not hot-linked. So I couldn't jump to those sections and just take a look and then jump back again."

Some students said they felt lost within the documents. They found it difficult to know their location within the document space, due to few contextual clues such as page numbers. They felt that more information about their location within the document space would have been beneficial:

> "I know it has a little bar on the side to say how you've progressed through the reading, but I'd still like something a little bit more . . . I've seen one somewhere on some computer screen that has percentages – how far you've got through the reading. I think something a little bit more obvious like that would be more helpful. I sort of like to know where I am in the reading."

Awkwardness of entering text. In general, students found the methods for entering text on the PDA to be slow and awkward. Typing on a full-size keyboard or writing on paper was deemed to be much faster and superior. A fold-out keyboard can be purchased for the Palms, but we did not supply students with this accessory. Tapping out letters on the PDA's small onscreen keyboard was slow and error-prone, while many students found the Graffiti handwriting system to be frustratingly inaccurate, as illustrated by the following interview comment:

> "I experimented with the writing part . . . and of course one of the problems was the letters weren't always coming out as I intended but I think that would have been a question of practice . . . So I got to the stage of being able to write and produce letters in print form on the screen but as it took a lot of time to do it I gave up."

There was recognition that the speed and accuracy of entering text may improve with practice. One interviewee said that her previous experience of using a Palm PDA had made it easier for her to use Graffiti:

> "I have to say probably my previous experience with a Palm Pilot helped. I'm very, very aware of that [the

Graffiti handwriting system] and have gotten much more skilful in it in the time I've had my Palm Pilot.''

4.2.4 Benefits of using the PDA for reading

Despite the limitations, several students also found there were benefits of using the PDA to read course materials. Most students countered their dislike for the limitations of the device with an appreciation for the advantages of being able to carry the course materials around in a small, lightweight device. A minority of students were primarily positive in their evaluation of the PDA; for these students, the portability and the fact that the device enabled them to have access to electronic versions of the course materials outweighed the limitations. Four students actually said they preferred reading course materials on the PDA to reading them on paper.

Portability. When asked what was the main benefit of using the PDA to read course materials, 22 questionnaire respondents referred to the portability of the device. The PDA was very lightweight, small and easy to carry around, therefore allowing easy access to course materials. As one respondent put it, the PDA meant the course materials were ''handy anytime anyplace.''

The PDA enabled students to read course materials in various situations, even while they were carrying out other activities. For example, one interviewee said he used the PDA while stuck in traffic. Another interviewee used the PDA to read course materials while in work meetings when the topic being discussed was not relevant to her. The PDA was an ''unobtrusive and neat device that could always be to hand.'' This enabled students to fit their study time more effectively around other activities:

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

Students also took advantage of the portability of the PDA to aid the process of revision, using it to re-read course materials when away from the desk or office environment. As one interviewee said, she used the PDA to reflect upon her learning while going about other day-to-day activities:

> ''It helped me reflect more on what I was reading because I would read a couple of sentences and have it near me, whatever I was doing, if I was doing something else as well, you know, practical kind of house stuff.''

Another student said that she felt the PDA provided the opportunity to review and build on what she had learned from reading the same materials on paper:

> ''Having the choice – between paper and Palm – meant that I felt like I could process more of the course materials, and consolidate my understanding of it; reading in one domain reinforced reading in the other domain.''

Students therefore used the PDA in conjunction with the printed materials. Having the course materials on the PDA gave students the opportunity to read those texts in situations in which it would have been difficult or inappropriate to read the A4 size printed materials. The PDA therefore became an extension of the printed materials, providing more opportunities for students to read and review the course materials.

Electronic text. A small number of students found that having the course materials in electronic format was beneficial. They took advantage of this by cutting and pasting sections of the text to aid the process of revision. For example, one interviewee said that she highlighted text by making it bold and then cut and pasted it into another document: ''which I would sort of lay out in sections, so I found ... not only would I have read back over the reading, I would have read the section of bits and pieces that I pulled out as well.''

In addition, some students recorded electronic notes, which they then transferred to the desktop computer to incorporate into more extensive documents: ''Note taking was easy and I could hotsynch to download notes to computer instead of having to copy type them up.''

Again, portability was considered an important issue. Being able to record notes electronically while away from the home or office enabled one interviewee to make more effective use of time:

> ''If I lugged the course materials to the kids' band practice and were to handwrite the notes, then I'd have to go and type them into the computer. But taking notes on the Palm from that point of view, was wonderful.''

4.3 Students' reading and note-taking habits

In the pre-questionnaire, students were asked about their interaction with course materials on the web, in conference messages, and in the set books used on the course. The post-questionnaire asked about their use of the printed Study Guide, which contained the texts that were made available on the PDA; the results comparing students' use of the printed Study Guide with the PDA materials are described in Sect. 4.3.2.

4.3.1 Strategies for reading print, web and conference messages

The pre-questionnaire findings show that all students print pages from the course web site, with a very high proportion (82%) reporting that they print pages 'frequently'. Nearly as many of them frequently print pages from other web sites as well. Conference messages are printed less frequently, although nearly all students print

them at least sometimes. These results suggest that students like having a printed copy of the course materials that are normally accessible electronically in web sites and conference messages.

When text is available electronically (on the web or as conference messages), students sometimes copy chunks of text to another file on their computer. They are slightly more likely to do this from the web than in the case of conference messages.

Students' note-taking habits were also explored. Paper is the most popular medium for note-taking. Nearly everyone takes notes on a separate piece of paper when reading set books: over half do this sometimes and two-fifths frequently. Over half of the students take notes on paper when visiting web sites and reading conference messages. A very popular activity is highlighting or underlining text in the set books (half do it frequently, a quarter sometimes). Writing notes in the actual books is considerably less popular, although the majority still do this at least sometimes.

Electronic note-taking is less popular. When reading information on web sites and in conference messages, students mostly do not type notes on their computer, though a minority do so sometimes. However, they are reasonably likely to type notes when reading from their set books for the course, with a substantial number (nearly half) reporting that they do this sometimes.

Finally, students were asked about their 'bookmarking' habits and noting the location of important information. It is clear that nearly everyone uses their browser to bookmark important web sites; in fact around three-quarters of students do this frequently. Half of the students sometimes keep a record of the location of important conference messages. When reading set books, half of the students make use of sticky post-it notes.

4.3.2 Strategies for reading print and PDA materials

The post-questionnaire results showed that using the PDA for reading changed the way students interacted with the learning materials, particularly with respect to the strategies they used for taking notes on the materials and highlighting the text. This section describes how such reading strategies were different when students read course materials on the PDA, compared with using the print-based version of the materials.

Taking notes. Figure 3 represents the post-questionnaire responses that reveal the note-taking strategies students used when reading course materials on paper and on the PDA. The figure shows the percentage of respondents who answered 'never', 'sometimes' and 'frequently' to each question. Response rates to each question represented in Fig. 3 varied. Nevertheless, it is apparent that students were more likely to take notes, in various forms, when using the paper version of the course materials. Some students, however, did take notes while reading course materials on the PDA. In addition, some students took notes on the PDA while reading the paper version of the course materials, as shown in panel (g) of Fig. 3. For example, in the online discussion conference, one student commented on her use of the PDA for recording notes while reading earlier sections (Sect. 1–2, available in print only) of the course materials:

> "To begin with I've been working through Sections 1 and 2 and making notes on the PDA using WordSmith. This seems quite easy. I hope that these notes will, when translated into Word documents, provide me with the input I need for the EC [examinable component]. Normally I would take notes on the computer so this saves me from balancing the block or book on my knee while typing at the computer."

Those students who did persevere with taking notes on the PDA devised strategies in order to overcome some of the difficulties associated with entering text on the PDA. For example, students ignored errors and took abbreviated notes, then transferred the notes recorded on the PDA to the desktop computer where they could be developed into more extensive documents:

> "The key thing was to get the notes down. If the odd character was wrong it was more time-consuming to go back and correct it than it would be just to sort it out when you've got it on the main machine."

Marking up text. Figure 4 shows the post-questionnaire responses that reveal tendencies to highlight, embolden or underline text when reading course materials on paper and the PDA. Again, students were more likely to highlight and underline text when using the paper version of the course materials. Nevertheless, there was a small minority who attempted to embolden and underline text on the PDA. One questionnaire respondent preferred to mark up text on the PDA, because it was neater:

> "It was easy to mark things up - this really paid dividends if I printed material out later, much neater than highlighter, pen, etc."

4.4 Further uses of PDAs as learning tools

The interview and online discussion comments also revealed that students were keen to explore further ways in which PDAs could be used to support learning activities beyond reading course materials. For example, some students who already owned a PDA described how they had used the tool to support different aspects of their studies:

> "I carry my bibliography around and use QuickWord to add references in libraries or from newspapers. This can then be sync-ed with the main document on my 'laptop'."

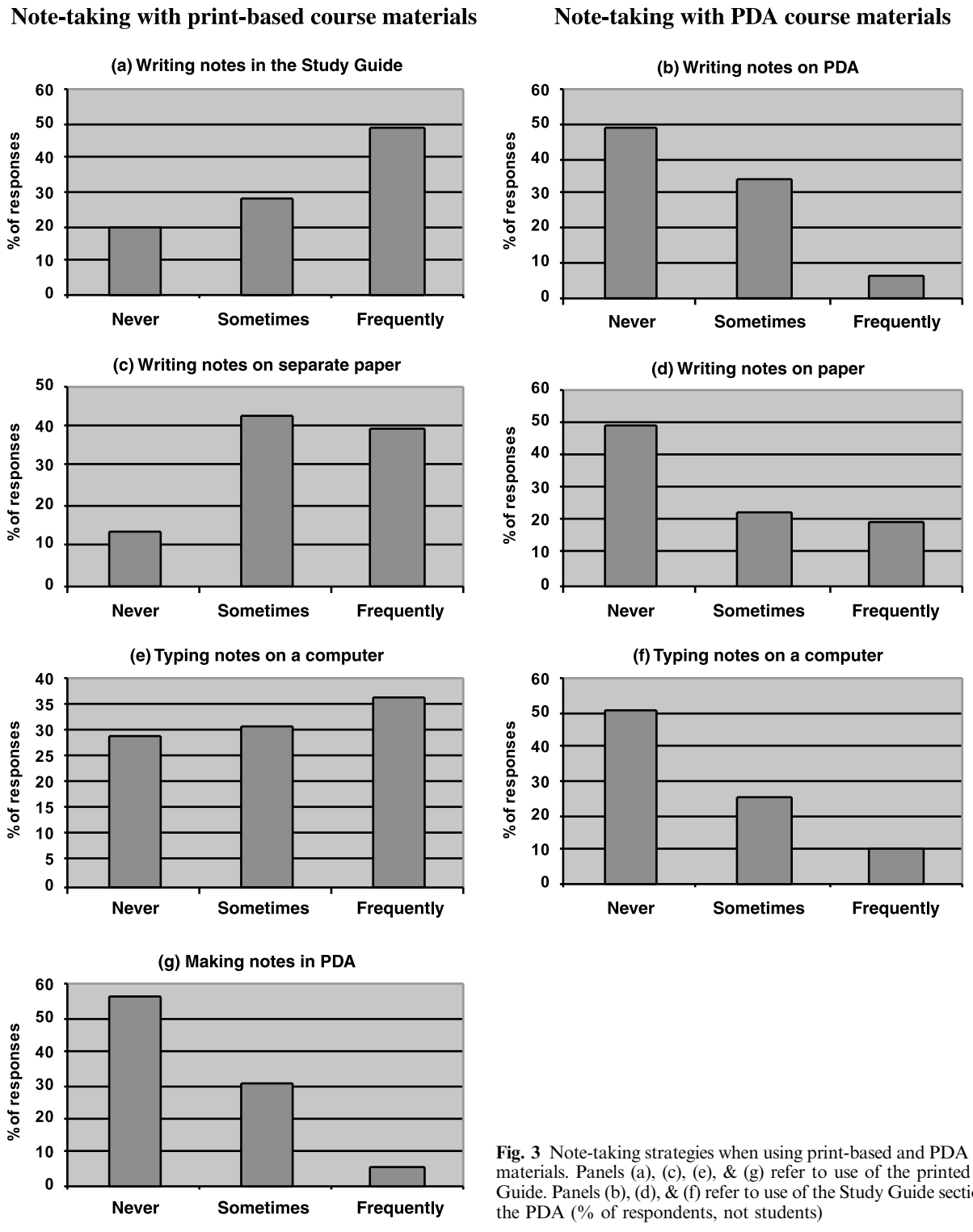

Fig. 3 Note-taking strategies when using print-based and PDA course materials. Panels (a), (c), (e), & (g) refer to use of the printed Study Guide. Panels (b), (d), & (f) refer to use of the Study Guide sections on the PDA (% of respondents, not students)

> "I've used it [the PDA] for the course to read and edit conference proceedings and compose postings."

Discussions about current and future uses of PDAs revealed an awareness of the potential for increasing functionality by using other devices in conjunction with the PDA. Discussions centred around the use of mobile phones for transferring data, such as emails and text messages, and there was also mention of the possibilities offered by connecting digital cameras to palmtop computers:

> "Sharp (I think) have designed tiny cameras – about the size of a tiny, single, lego brick and half the depth, which could be embedded into the Palm and used for video conferencing. The future seems to lie with

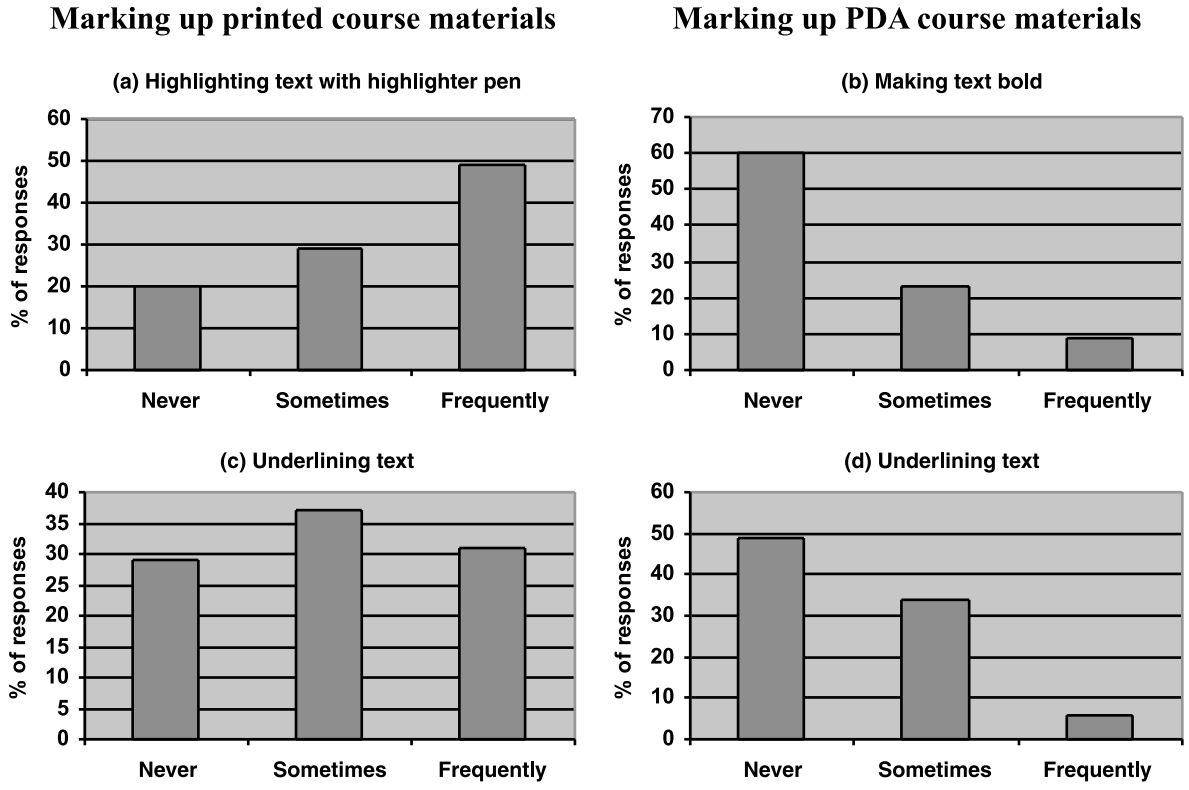

Fig. 4 Marking up print and PDA course materials. (a) & (c) refer to use of the printed Study Guide; (b) & (d) refer to use of the Study Guide sections on the PDA

> PDAs that are compatible with phones to allow access to the internet and/or video conferencing. Just the sort of thing we H802 students could do with when travelling.''

These comments suggest further possible ways in which PDAs might support learning activities, and reveal that some students were keen to explore other potential uses of PDAs as learning tools.

5 Discussion of findings

This study revealed benefits and limitations of students' use of PDAs for reading course materials. While the portability of the device was generally welcomed, and some students took advantage of having access to the electronic format of the course materials, limitations such as the small screen size, navigation difficulties, and slow and error-prone methods for entering text, made it difficult to read documents on the PDA. In addition, use of the PDA changed the way students interacted with the text. They were less likely to take notes and highlight text when using the PDA, compared with the strategies they employed when reading print-based materials. In the following section, the findings are discussed with reference to the way the new tool changed the reading task.

5.1 How the PDA changed reading

As Carroll et al. [25] suggest, the possibilities and constraints introduced by a new tool do change the task that tool is used to support. This study showed that the use of a PDA for reading course materials changed the reading task, by giving students new possibilities, such as 'anytime, anywhere' access to learning resources, and introducing constraints such as small screen size. With the PDA, students could carry course materials in a small, lightweight and unobtrusive device, which was more portable than the A4-size print version of the course materials. Using the PDA, students could read course materials while engaged in other activities or during short periods of time which would otherwise be wasted, such as while travelling or waiting for an appointment. This meant that reading course materials did not have to be confined to office or home contexts, and it was not so important to set aside study time. As one interviewee said: ''with reading from paper I'd feel I'd have to sit down at it more and that just becomes a bit more of an ordeal sometimes.''

However, despite positive feedback from students about the benefits of having the course materials on a portable device, most students found it difficult to read text on the PDA. The limited display area on the PDA meant that only a few lines of text could be viewed at any time. This made it difficult to scan through the text, and required a more concentrated line-by-line reading strategy. In addition, the ease with which students could flick through paper documents was missing on the PDA. Students found it difficult to move back and forth

between sections, and they were unable to easily assess their location within the document space. This contributed to feelings of being 'lost' in the reading materials and to an inability to gain an overview of the documents. Students liked the affordances of paper; for example, being able to flick through the document and skip ahead to see how long a section was. This finding is similar to the results of past research that has compared reading from paper with reading from a computer screen [14,16]. The contextual clues that are available when reading printed documents, such as paper size and document weight, are missing with electronic text. Therefore, it is important for electronic documents to contain other contextual clues, along with more flexible navigational tools such as hyperlinks connecting sections of text.

A further constraint of the PDA was the difficult means of entering text. This is one of the general usability problems of the present generation of palmtop computers and is another consequence of their small size and portability [28]. Students generally found it difficult to use the onscreen keyboard and handwriting recognition system on the PDA. They found these text-input mechanisms to be much slower and less accurate than writing on paper or typing on a computer. Consequently, students were less likely to take notes while reading on the PDA, compared to reading on paper. In any case, the note-taking findings from the pre-questionnaires indicate that students mostly write notes on paper (separate to the paper they are reading from), that they like to highlight or underline printed text, and that they might type notes on a computer whilst reading from paper. Students do not appear to have developed the habit of making notes electronically when working with electronic text. This may partly explain some of their reluctance to make notes on the PDA.

In addition, students tended to use both the printed version of the materials and the PDA, depending on the context in which they were studying. Therefore, they may have reserved note-taking and highlighting strategies for when they were using the printed materials, and used the PDA solely for reading the documents. It may have been difficult to take notes in the circumstances in which students were using the PDA (e.g. while travelling), whereas reading the printed materials in a home or office environment would have been more conducive to note-taking. Nevertheless, some students did take notes on the PDA. They found it beneficial to be able to take notes in electronic format at any time, wherever they happened to be. They devised strategies to overcome limitations of the PDA, using abbreviated notes, which they transferred to the desktop computer to be incorporated into more extensive documents. Students therefore used the PDA in conjunction with other tools, suggesting that PDAs are not 'mini-computers' that replace the need for a desktop computer. Nor are they 'e-books' that replace the need for printed course materials. Instead they are used to support and extend other technologies and resources.

5.2 Limitations of the study

The Palm m105 PDA used in this study is one of the lower-end PDA models, chosen partly because of its relative affordability given the financial resources that were available for this project. Screen quality on this PDA is not as good as that available on more expensive PDAs, some of which have colour displays and a slightly larger screen area. In addition, in some post-study workshops, we found that the touch-sensitive screen of many of the devices was inaccurate, making it difficult to enter text and manipulate icons effectively. Thus, the lower-end model of PDA chosen for this study may have adversely affected students' experience of using a PDA for reading course materials. While the provision of a more expensive PDA was not an option for this evaluation study, a handheld computer designed specifically for reading electronic text (i.e. an e-book reader) may have been a more appropriate choice. However, at the time the study began, such devices were not widely available and were relatively heavy (typically the weight of a hardcover book). We also speculated that these specialised devices would be less useful to our students in the longer term (i.e. beyond the evaluation study) than the general purpose PDAs. Indeed, the results of this study showed that students did use the PDA as a general tool for supporting time and information management. For example, they used such facilities as the diary, address book, to-do list and the notes or memo pad applications. When rating how useful the PDA was as a general tool, the majority of questionnaire respondents (77%) said that it was somewhat or very useful.

Students received the PDAs during the final block of the course and many interviewees commented that they did not have sufficient time to learn to use the device. At this time they were busy preparing to submit their final assignment and their examined project. Interview comments suggested that students felt they needed more time to become familiar with all of the features and functions of the device. They were unable, therefore, to make full use of the PDA during the course. They would have preferred to receive the PDA at the beginning of the course when they could familiarise themselves with it and integrate it more effectively into their study activities.

The timing of the post-questionnaire was also problematic. By the end of the study there were 61 students enrolled in the course. However, only 35 students responded to the post-questionnaire. This raises issues about the possible reasons that 26 students did not respond to the post-questionnaire. It may be that these students had rejected the PDA outright, or they had attempted to use it but found it too difficult to read from. In this case, the findings would have indicated a more positive evaluation of students' use of the PDAs than was actually the case. Another possible explanation is that some students may have made a conscious decision not to use the PDA because of time pressures at that stage in the course; in that case, their non-response

does not imply a negative attitude or experience with reading from a PDA. However, the response rate may also have been adversely affected by the fact that the questionnaire was not administered until a month after the course had finished. Students would therefore not have felt obligated to take part in the questionnaire. We can only speculate, however, on the reasons for the poor response rate and how the findings might have been different if all students had taken part in the questionnaire. In any case, the findings showed mixed views about the value of using PDAs to read course materials and we can only assume that these responses are representative of the range of responses we might otherwise have received.

The use of questionnaires and interviews as the main evaluation methods could also be problematic due to the fact that both are self-report methods, and are therefore subject to potential bias. That is, students may have provided responses they believed the evaluators wished to hear, rather than a totally honest account of their perceptions of the PDA. However, given the mixture of positive and negative assessments of the PDA, this seems unlikely.

The study may also have been affected by the subject matter of the course: 'applications of information technology in open and distance education.' It may be that students on this course were more receptive to using a new technical tool than other students from less technology-related disciplines. Therefore, students who took part in this study may have been more enthusiastic about the possibilities of using a PDA and sought to evaluate it more positively than other students may have done. It would be helpful, therefore, to conduct further evaluations of PDAs using students from less technology-oriented subjects. However, it must be said that an advantage of using students from a course such as this is that students were generally very aware of how they used technology to support their studies and so they were articulate in their evaluation of the PDA as a learning tool.

5.3 Implications for future use of PDAs as learning tools

The course materials used in this study were not reformatted specifically for presentation on the PDA. Instead, they were presented in their original Word document format. Findings from this study suggest that in future it may be advantageous to reformat the documents with more salient contextual clues about the reader's location within the document and more flexible navigational tools, such as hyperlinks, to allow students to move with ease back and forth within the documents.

Furthermore, this study looked at the use of text-based documents. The document reader software used in this study did not support the presentation of graphics. Therefore, further investigation could be made to determine whether it is feasible to view graphics on PDAs and other small screen devices.

The findings showed that students did appreciate having access to learning resources while on the move. It is important to note, however, that the PDA did not necessarily replace the paper copy of the course materials. Instead, the PDA was used in addition to the printed documents and was used in conjunction with other tools such as the desktop computer. For example, some students liked being able to record and store electronic notes on a portable device, which could then be easily transferred to the desktop computer for further work. Therefore, the possibility of using PDAs to support learning in this way should be further explored. However, it is important to consider the limitations imposed by the device, such as small screen size and poor screen quality. The choice of device is important. If students intend to use a palmtop computer primarily for reading large amounts of text, it may be preferable to choose a device designed specifically for that purpose, such as an e-book reader. Alternatively, for general use, it is advised that students choose a PDA with a larger and better-quality screen than that of the Palm m105 PDA used in this study.

This study also showed that there are several ways that PDAs could be used to support learning activities beyond reading course materials. Most students found the PDA to be useful as a general tool. In particular, several students saw advantages in using the PDA as a communication tool. Comments made in the online discussion conference revealed that some students used their PDA in conjunction with mobile telephones to send and receive emails when they were away from their computer. They also downloaded and composed conference messages on the PDA. In addition, several students used the PDA to access Internet resources, such as online newspapers and other web sites. The potential for PDAs to be used as learning tools extends beyond the ability to read electronic text. As PDAs with built-in modems or mobile phones become more widely available, it may be possible to further explore such potential uses of PDAs, particularly for supporting communication aspects of learning activities, such as the use of web-based computer conferencing in distance education.

6 Conclusion

This paper reported the results of an evaluation study of students' use of PDAs for reading course materials. The results show that the PDA introduced both new possibilities and constraints to the reading task, which changed the way students used the course materials. In particular, the portability of the PDA made it possible for students to have access to learning resources 'anytime, anywhere', which many students found to be very beneficial. However, limitations, such as the small screen size of the PDA, awkward methods for entering text, and navigational difficulties, meant that reading on the PDA was constrained. Fewer students took notes and highlighted text on the PDA than they did with printed

materials. Furthermore, the small screen size of the PDA required a more concentrated reading strategy and made it difficult to scan-read the text. Students therefore found it difficult to read on the PDA and it was generally considered to be inferior to reading on paper.

Nevertheless, there were some students who really valued the PDA for particular reasons, for example as an aid in the preparation of assignments, as a means to neater notes, as a reference management tool, as a useful tool for composing conference messages on the move, or just as a tool that fitted in with their lifestyle. These students may have been more tolerant of the PDA's shortcomings as a reading device. It would be interesting to investigate the relative value of different functions of the PDA to individuals and groups in learning contexts.

The study also showed that there are several potential uses of PDAs as learning tools beyond reading course materials. In particular, students suggested that they would have liked to be able to use the PDA as a communication tool, particularly for supporting activities such as online conferencing. It would be valuable, therefore, for further studies to investigate the potential benefits and limitations of using PDAs for these learning activities.

Acknowledgements This evaluation project was funded through the award of an Open University Teaching Fellowship in 2001 to the course and presentation team, 'for innovation and excellence in global online course delivery.' We would like to say a special thank you to colleagues in the Institute of Educational Technology who gave us vital technical and logistical support throughout this project: Will Woods, Phil Downs, Helen Cottrell and Liz Burton-Pye. Thanks are also due to Gill Kirkup for providing feedback on an earlier draft of this paper and to Eileen Scanlon and Ann Jones who provided helpful advice during the project.

References

1. Stonier T (1991) Futures: The personal electronic pocket-book. Educational and Training Technology International 28: 364–368
2. Fung P, Hennessy S, O'Shea T (1998) Pocketbook computing: a paradigm shift? Computers in the Schools 14: 109–118
3. Hennessy S (1997) Portable technologies and graphing investigations: review of the literature. CALRG Technical Report 175, Institute of Educational Technology, The Open University, Milton Keynes
4. Hennessy S (2000) Graphing investigations using portable (palmtop) technology. J Computer Assisted Learning 16: 243–258
5. Sharples M (2000) Disruptive devices: personal technologies and education. Educational Technology Research Paper Series 11, The University of Birmingham
6. Sharples M (2000) The design of personal mobile technologies for lifelong learning. Computers & Education 34: 177–193
7. Soloway E, Norris C, Blumenfeld P, Fishman C, Krajcik J, Marx R (2001) Log on education: handheld devices are ready-at-hand. Communications of the ACM 44: 15–20
8. Robertson SI, Calder J, Fung P, Jones A, O'Shea T, Lambrechts G (1996) Pupils, teachers & palmtop computers. Journal of Computer Assisted Learning 12: 194–204
9. Robertson S, Calder J, Fung P, Jones A, O'Shea T (1997) The use and effectiveness of palmtop computers in education. British J Educational Technology 28: 177–189
10. Young JR (2000) A university that reveres tradition experiments with e-books. The Chronicle of Higher Education Information Technology (available from htttp://chronicle.com/free/v47/i36/36a03901.htm)
11. Dean KS. (2001) Dakota gives palm thumbs up. Wired News 2001 (available from http://www.wired.com/news/school/0,1383, 43367,00.html)
12. Jones A, Kirkup G, Kirkwood A (1992) Personal computers for distance education: the study of an educational innovation. Paul Chapman Publishing, London
13. Harrison BL (2000) E-books and the future of reading. IEEE Computer Graphics and Applications, 32–39
14. Dillon A (1994) Designing usable eectronic text: ergonomic aspects of human information usage. Taylor & Francis, London
15. Want R, Borriello G (2000) Survey on information appliances. IEEE Computer Graphics and Applications, 24–31
16. O'Hara K, Sellen A (1997) A comparison of reading paper and on-line documents. In: Proceedings CHI 97 ACM Press, Atlanta, GA, pp 335–342
17. Schilit BN, Price MN, Golovchinsky G, Tanaka K, Marshall CC (1999) As we may read: The reading appliance revolution. Computer 32: 65–73
18. Hayter M, Kistler J, Chaiken J, Redell D (1997) Virtual book: a portable reading appliance. (available from http://www.research.compaq.com/SRC/articles/199710/vbook.html)
19. Schofield J (2000) The e-book: and now a new chapter begins. The Guardian Online, pp 2–3
20. Adler A, Gujar A, Harrison BL, O'Hara K, Sellen A (1998) A diary study of work-related reading: design implications for digital reading devices. In: Proceedings CHI 98, ACM Press, Los Angeles, pp 241–248
21. O'Hara K, Smith F, Newman W, Sellen A (1998) Student readers' use of library documents: Implications for library technologies. In: Proceedings CHI 98, ACM Press, Los Angeles, pp 232–240
22. Marshall CC, Price MN, Golovchinsky G, Schilit BN (1999) Collaborating over portable reading appliances. Personal Technologies, 3
23. Marshall CC, Price MN, Golovchinsky G, Schilit BN (2001) Designing e-books for legal work. In: Proceedings JCDL 2001, ACM Press, Roanake, pp 41–48
24. Bergman E, Haitani R (2000) Designing the PalmPilot: a conversation with Rob Haitani. In: Bergman E (ed) Information appliances and beyond: interaction dsign for consumer products, Morgan Kaufmann, San Francisco, CA, pp 81–102
25. Carroll JM, Kellogg WA, Rosson MB (1991) The task-artifact cycle. In: Carroll JM (ed) Designing interaction: psychology at the human-computer interface. Cambridge University Press, Cambridge, pp 74–102
26. Zuberec S (2000) The interaction design of Microsoft Windows CE. In: Bergman E (ed) Information appliances and beyond: interaction design for consumer products. Morgan Kaufmann, San Francisco, CA, pp 103–129
27. Schmidt A (1999) Implicit human computer interaction through context. In: Proceedings second workshop on human computer interaction with mobile devices: Interact 99, Edinburgh
28. Pascoe J, Ryan N, Morse D (2000) Using while moving: HCI issues in fieldwork environments. ACM Transactions on Computer-Human Interaction 7: 417–437