

# Reading-in-the-Small: a study of reading on small form factor devices

Catherine C. Marshall  
Microsoft Corporation  
One Microsoft Way  
Redmond, WA 98052 USA  
+1 425 705 9057  
cathymar@microsoft.com

Christine Ruotolo  
Electronic Text Center  
University of Virginia  
Charlottesville VA 22903 USA  
+1 804.982.2652  
cjr2q@etext.lib.virginia.edu

## ABSTRACT

The growing ubiquity of small form factor devices such as Palm Pilots and Pocket PCs, coupled with widespread availability of digital library materials and users' increasing willingness to read on the screen, raises the question of whether people can and will read digital library materials on handhelds. We investigated this question by performing a field study based on a university library's technology deployment: two classes were conducted using materials that were available in e-book format on Pocket PCs in addition to other electronic and paper formats. The handheld devices, the course materials, and technical support were all provided to students in the courses to use as they saw fit. We found that the handhelds were a good platform for reading secondary materials, excerpts, and shorter readings; they were used in a variety of circumstances where portability is important, including collaborative situations such as the classroom. We also discuss the effectiveness of annotation, search, and navigation functionality on the small form factor devices. We conclude by defining a set of focal areas and issues for digital library efforts designed for access by handheld computers.

## Categories and Subject Descriptors

H.3.7 [Information Storage and Retrieval]: Digital Libraries – *User issues*; K.3.1 [Computers and Education]: Computer Uses in Education – *Collaborative learning*; H.5.2 [Information Interfaces and Presentation]: User interfaces – *Evaluation/methodology*

## General Terms

Design, Documentation, Human Factors, Performance

## Keywords

E-books, handheld computers, field study, education, digital libraries, reading, annotation, collaboration

## 1. INTRODUCTION

Small general purpose handheld computers and PDAs such as Palm Pilots and Pocket PCs are becoming increasingly ubiquitous in the educational settings [8, 14]. These devices are useful for organizing personal information and for other specialized tasks in the classroom; but are they suitable for activities like reading? We normally associate such complex intellectual endeavors with the printed page, or at least with much larger displays. Even special-purpose reading devices for education, like the goReader [6], are

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

JCDL '02, July 13-17, 2002, Portland, Oregon, USA.

Copyright 2002 ACM 1-58113-513-0/02/0007...\$5.00.

designed to provide the student with a bigger display area. What utility will smaller (and more general purpose) devices bring to the classroom, and more generally, to an educational institution's digital content?

It is productive to examine this technology-centered question from the standpoint of digital documents and their use [10]. Over the last decade, digital libraries have arrived as significant resources for education. This growing use of digital materials poses a series of larger questions that frame the study described in this paper: How will students read these materials? How will they use them in the classroom and in their assignments out of class? How will the digital materials used in an educational setting interact with paper materials in that setting? It is easy to envision a situation in which "turn to page 47 in your textbook" is a problematic instruction for a class that is using several editions of a text along with various sizes of digital displays.

The study described in this paper investigates these issues through a technology intervention in an academic environment. The technology intervention centered on a deployment of Pocket PCs (HP Jornada), including reading software (Microsoft Reader) and specially-prepared digital library materials (class reading assignments and background materials from course syllabi). The technology was used on a voluntary basis in two different humanities classes that required a substantial amount of reading, writing, and classroom participation. One course was at the undergraduate level, the other was a graduate course. Digital materials were accessible in multiple formats, including HTML for viewing in standard Web browsers; some course materials were also available in print. Students were by-and-large comfortable with computer technology; most had their own computers at home, and were familiar with the university's computer infrastructure (for example, how to search on the Web and how to print documents from computers in the library).

Given the rich use situation that the university offered through this technology intervention, we entered the picture with the following set of questions, a mix of practical concerns and theoretical interests that should be useful for informing the design of future reading technologies:

- What is the role of small form factor devices in reading and the reading-related activities associated with digital libraries? Can they be effective vehicles for reading?
- What kinds of materials will students choose to read on small form factor devices? Which functionality is useful (and indeed practical) to support reading these materials?
- What are the relationships among different forms of the same materials (e.g. paper books, digital materials on a laptop or desktop computer, digital materials on a handheld,

printouts, etc.), and how are they used in reading-related activities?

- Can digital library materials be used effectively in the collaborative situation of the classroom, given our reading technologies? What are the barriers and facilitators to doing so?

Finally, we wanted to get a foothold on an overarching concern that is bound to make a difference for the future of reading, given the current state of heterogeneous paper/digital collections in today's libraries, by asking:

- Is reading on the screen fundamentally different from reading on paper?

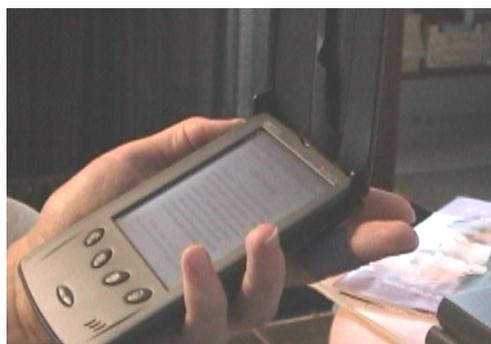
The last question is a difficult one. Certainly reading is a complex activity whether it involves a paper book or document or wholly digital materials. But we have found through interaction with a range of computer users that reading on the screen may well be regarded differently than reading on paper; for example, on a computer screen "reading e-mail" may involve sorting and replying to e-mail as well as reading individual messages. In general, people seem to choose to read different materials on the screen than they read on paper, and when they read on the screen, they read with a different set of purposes in mind.

We will first describe the study and the digital library materials the two courses used; we will go on to discuss our findings, and their implications for design. We will conclude by defining some focal areas for future work and issues we still are seeking to resolve.

## 2. STUDY DESCRIPTION

The study described in this paper was conducted as part of a longer-term investigation and deployment implemented by the University of Virginia's decade-old Electronic Text Center (Etext), which is part of the university's library system. Their mission is twofold: to provide access to humanities-related electronic texts, and to train and support patrons in their creation and use. The Electronic Text Center was responsible for initiating the overall project, preparing the materials in the appropriate formats, and supporting the on-going use of the technology throughout the deployment.

The Electronic Text Center supplied the students, faculty members, and the TA in two classes with Pocket PCs to use during a normal school term and provided technical support to the participants throughout the term. The Pocket PCs (HP Jornadas, as shown in Figure 1) were used by an undergraduate religious studies course and a graduate seminar in English literature. Each student in the classes, the professors and the TA for the classes, and all of the staff members involved in this effort had their own Pocket PCs, pre-loaded with the relevant materials in Microsoft Reader e-book format. Both courses required a substantial amount of reading, and had significant corpora of secondary readings and references. The course materials represented a mix of genres – everything from historic documents to literary criticism to drama to poetry to lengthy Victorian novels. Much of the assigned material was available electronically. Some of the materials were also readily available as paperback books in print; other portions of the materials were drawn from the university's rare book collection or out of print and thus difficult for the students to access in traditional book form.



**Figure 1. HP Jornada Pocket PC running Microsoft Reader software**

Project participants used the Pocket PCs for the duration of the courses. They used the handhelds in class, in normal study situations, in transit, and when they traveled out of town. A few of the students borrowed the cradles (available through the Electronic Text Center) to download other reading materials, games, and software, although this practice was less common and more obstacle-prone.

We conducted semi-structured open-ended interviews with 10 students from the two classes (six out of 22 undergraduates and four out of 18 graduate students, roughly a quarter of the student participants), with the two professors, with the TA for the undergraduate course, and with the Electronic Text Center staff members central to the text preparation process, including a programmer and a mark-up specialist. We also attended and observed the undergrad class and lab sessions. Neither author was involved in evaluating the students in the courses.

The interviewees were self-selected by their willingness to discuss the way they work and their experiences with the Pocket PCs; they were told they did not need to be proponents of the technology, nor even use it, although it is likely that among the interviewees were the most active users of the Pocket PCs. In fact, four of the interviewees used the handhelds extensively and enthusiastically; five used it less frequently, but still found it a productive technology for their work; and one of the interviewees tried it initially, but quickly gave up on it. Because the participants in our study represented the most avid users among the students, we can conclude that a little less than a quarter of the forty students in the study used the technology for the entire term.

For half of the students interviewed (the four graduate students, and one of the undergraduates), the course was in their major field; for the other half (the other five undergraduates), the religious studies course was chosen out of interest, but not in their major. All were full-time students in their twenties. All owned at least one usable computer of one sort or another; all were familiar with email; and all had used the Web. Many had printers. None of the students seemed unusually technologically savvy; nor were any particularly technophobic.

The interviews took place in "usual" work places. For the students, this included off-campus apartments and rooms (mostly) and a few sites on campus; the students all lived off-campus. The interviews and class sessions were videotaped to supplement and verify the field notes. All participants were offered software as honoraria to acknowledge the value of their time and their willingness to be part of the investigation.

## 2.1 About the Materials

The collections representing the primary and secondary materials for the two courses came from multiple sources. Some of the works began as microfilm; some were online books in other formats; others were in PDF; still others, from a publisher's database, were in non-TEI SGML. Thus, the Electronic Text Center's conversion process was necessarily complex, and at times involved OCR and occasional keyboarding when the original paper texts were not machine-readable. The Electronic Text Center's canonical target format is TEI-conformant SGML, which can be processed in a semi-automatic way (usually through PERL scripts) either for direct output to a web browser or for conversion to extended Open eBook (OEB) format, from which multiple proprietary e-book formats can be generated. The professors worked closely with the Electronic Text Center to ensure the texts met the courses' needs. The conversion process is described in greater detail in [5].

The religious studies course syllabus consisted of 37 works of various lengths (from single pages to full-length novels) available in e-book or HTML format, 20 works (mostly article-length) available as PDFs, and 5 books that could be purchased in the bookstore (some of the same books could also be purchased at local used bookstores at a discount). Forty-one e-books or HTML files were available for the graduate-level course, including a seven-volume critical work. Most of these were longer works.

## 2.2 About the Technology

The HP Jornada Pocket PC, shown in Figure 1, is a handheld general purpose computer running the Windows CE operating system with limited versions of most of the common Microsoft software (e.g. Word, Outlook, and Internet Explorer). It has a backlit color display, 240 x 320 pixel LCD, and has a pen interface. It can be connected and synched with a standard Windows PC using a dock.

The students used the Microsoft Reader e-book software to read the course materials. The Reader software's emphasis has been on readability and support for simple kinds of user interaction – bookmarking, annotation (highlighting and notes), within-document word search, and the ability to perform page and link-based navigation. The Microsoft e-book format is based on the OEB standard [15].

## 3. FINDINGS

Past work has shown us that reading (in particular, the purposeful reading we associate with students and other knowledge workers) is a highly variable activity, frequently involving non-linear access to content, the use of multiple documents, and the pursuit of related goals [1]. Dillon's survey of the reading literature also concludes that while reading on the screen may have some performance drawbacks, preference seems to be one of the primary reasons people have chosen to stick with paper as their vehicle for reading [4]. From more recent studies, we also know that mobility is a key attribute of paper that must be used to draw readers to e-books [13]. Past work has shown that paper offers readers advantages in terms of ease of annotation, ready navigation, and the flexibility of spatial layout and juxtaposition [16]; it has also shown that any introduced e-book technology must demonstrate a clear advantage over paper in these areas if it is to be adopted by users [12, 17].

Indeed, as Adler and her co-authors predict, what the students, staff, and faculty do with materials on the handhelds blurs all distinctions among reading, browsing, and searching. The students skip around in the texts, focusing on some parts more closely than others. Much of the students' actual reading on the handheld could be characterized as skimming, reading very quickly in a time-constrained situation. The ability to locate and focus on short segments of a longer text and navigate through an extensive set of familiar materials is frequently cited as a strength of reading on the screen.

Previous work suggests, then, that student adoption of the Jornadas will depend on the outcome of a series of trade-offs. These trade-offs weigh the advantages of reading on such a small factor device (smaller than most books, and certainly more compact than the collection of readings for a course) and the unique functionality of reading on a computer (the ability to search, for example, and the ability to follow hypertext links) against the affordances of paper, in particular in the areas mentioned above. Because the students have their choice of formats (e-book, HTML in a Web browser, and the stable paper page) and reading vehicles (book, printout, desktop computer, laptop computer, or handheld), we have been able to learn how the trade-offs play out.

Figure 2 is an excerpt from a student interview that provides an account of the reading on the Jornada she did to prepare for a class session earlier in the day. We will refer again to this portion of transcript in some of the more detailed discussions of specific trade-offs and functionality later in the paper. The excerpt is presented as a single quotation for the sake of coherence. This account typifies the kind of reading that the Pocket PC is valued for – episodes in which a student reclaims an otherwise difficult to use brief period of time by quickly finding, reviewing, and possibly marking on portions of a larger text. The interviewer's brief interjected acknowledgements (all phatics such as "okay") have been omitted.

In this detailed account, we can see several important characteristics of the way the student is reading the text to prepare for class. First, she does not read linearly; she looks for paratextual cues (like chapter headings) and uses these in combination with a search facility. Second, when she is engaged with the text in a more linear fashion, she is moving both forward and backward, alternating between skimming and focused reading, all the while conscious of reclaiming just enough context to make sense of what she's reading; she characterizes both her move *into* and *out of* the desired passages as skimming. She highlights in a purposeful way, so she can find the passage again when she brings the device to class.

Most importantly, she evaluates how much time she has, and what ground she can possibly cover in this time. Among the students, this is seen as a significant reason for reading on the Jornada – it is easy to carry (a "no-brainer") and the student can pull it out, and with little ado, read a small amount whenever there is time wherever he or she is. Students talked about reading in line, while they were waiting for the bus, on travels out of town, and in other venues (for example, at work as a hostess in a local restaurant) in which it would have been impractical to carry and bring out a weighty set of secondary readings. There is little risk of overpacking in bringing the Jornada along, since it is so small and relatively durable.

"This week [the professor] asked us to – I don't know if you got the assignment – to look at an early 19<sup>th</sup> century critical text that relates in some way to the 18<sup>th</sup> century reading we've been doing... So I pulled this up. I can't remember. I started here. .... I didn't really know what I was looking for. I didn't remember, because it was a few years ago that I was looking at it, and I was only looking at particular sections last time I was looking at it. So I didn't really remember – I don't have any sense of what is in the *Biographia*, and what I'm looking for.

...

So I'm, okay, begin at the beginning. Chapter 1. And I read the heading to Chapter 1. It would be really nice if there were a table of contents to this. There isn't. Um. [pause] So Chapter 1. I get to the end of the description of what's in the chapter. It says, 'Comparison between the poets before and since Mr. Pope.' Well that sounds like right up my alley. And I can see that's kind of at the – see, there's this long description of Chapter 1.

...

And that's at the end of – so I think I used, I searched for 'Pope' to find where that discussion comes in that I would be interested in. Um. And I've annotated that so I can, so... Where he is talking about the writings of Mr. Pope?

...

So then once you find – so I basically searched for 'Pope' and got to this page. Which was page 43 in the Reader. Well, once I'm there, it's obviously in the middle of a paragraph, in the middle of a section. So in order to – this is my usual MO – in order to get an idea of where I am, and what he's talking about, and sort of get oriented, I have to scroll up a little bit. Well, the beginning of the paragraph is, 'The second advantage, which I owe to my early perusal.' I still need more context. I need to find out what he's talking about. So I go back, skim read, get a picture of what he's talking about. Then I scroll forward again to where I landed and start reading more seriously now that I've got the gist of sort of the context.

...

So of this I'm starting to skim more. Um... As it talks about things that are less relevant. Um... I can't remember – here's another highlight, so I definitely read this far. Uh. I think I read to the end of the chapter. Yeah, there's another highlight.

...

And then, I said, 'Okay. I have another 10 minutes before class, 20 minutes before class. What can I do?' So I started out just looking at, just reading the chapter headings for the chapter. ..

...

I read. 'Supposed irritability of men of genius. Brought to the test of facts. Causes and Occasions of the charge--Its Injustice.' Well, this does not sound like this going to have a lot of discussion of 18<sup>th</sup> century writers. It might. But it's not – in the economy of, 'I have 10 minutes before class', this isn't too promising.

...

I eventually got to – I think it was chapter 16 – but I'm not sure of that. Go to the annotations index. [pause] Okay. I think, see I've got two annotations. One is 'poets of the present age,' and the other is 'in the present age,' and I can't remember which of them is the start of the other section that I wanted to look at. Um... Let's try 'poets...' Oh, yes. Poets of the present age. Chapter 16. Oops. 'Striking points of difference between the Poets of the present age and those of the 15th and 16th centuries--Wish expressed for the union of the characteristic merits of both.' This looks pretty relevant to what I was looking for. So I started reading. And... So yeah, so there's some – like almost the whole page is highlighted, because it was all, 'oh! This is what I would read out in class if I if I were saying, this is what I found in the text.'"

**Figure 2. Student's account of reading for the class earlier in the day**

We can now look in more detail at the issues raised by the technology. First, we can examine the trade-offs the students evaluated when they chose how to read the assigned texts. In particular, we will focus on how portability weighs in against concerns for readability and preserving the literary experience. Second, because the handhelds were used to support work in the classroom, we will examine the issues that arose when the students and faculty used the Jornadas together, including how they learned from each other how to use the technology more effectively. Finally, we will look at some specific aspects of functionality: what kinds of support can and did the handheld device offer to readers?

### **3.1 Portability, Readability, and the Importance of Form**

From our past experiences and related work, we know that mobility is key to reading. Certainly one of the key strengths of the Jornadas is their compact physical form; this allowed the students to carry the handheld routinely, even if they thought it

relatively unlikely they would have a chance to use it. For example, one student carried it home with him during spring break with the idea he might read course materials:

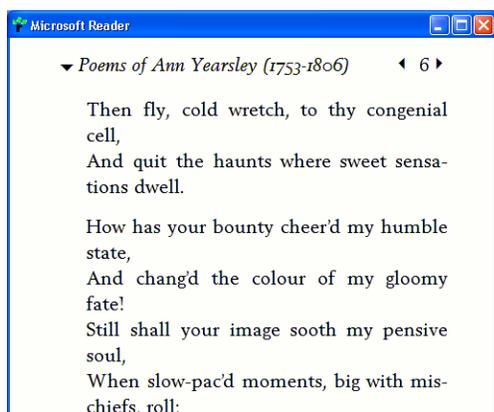
"I took it home with me when I went home to Colorado. It was extremely nice to carry this and not a bunch of books. I didn't really have any assignments... if I'm going home to Colorado, I have to really be sure I'm going to read something if I'm going to bring it. Otherwise, why should I bring it? This thing [the Jornada], I was like, 'I'll bring it, and if I read it, I read it; if I don't, I don't.' It doesn't matter. It's small, it's handy."

On the other hand, although the display is color and high resolution for its size, it is still relatively small when one compares it to a printed page. Thus the ready portability of the handheld must outweigh the disadvantages of reading on such a small screen; for example, sometimes long sentences cannot be rendered on a single page, and even a brief article is many pages long. In our study, the two most important consequences of

rendering a page on a small screen are the effects of having so little text visible at once on maintaining reading context and the effects of the difference of form on the reading experience in general.

Certainly on a larger display surface, improvements in layout and typography (for example, Microsoft's ClearType, a sub-pixel rendering technique) are desirable for the sake of readability. On a smaller display, the improvements must be evaluated to determine whether better readability is worth any sacrifice in the amount of text displayed. For example, a student familiar with one of the popular wireless news services made the explicit comparison between the two modes of text presentation, and found that she would rather see more text – for the sake of improved context – than read a better typographical rendering that shows fewer words on the page.

One of the other consequences of Microsoft Reader's reflowable page layout was that text adapted itself to the smaller display, regardless of the genre of materials being presented. Project participants reported that certain kinds of materials were very sensitive to layout, and that changing the layout changed their perception and understanding of the materials. The recurring example was poetry, particularly structured verse forms like rhyming couplets. Different participants cited different poems, but all had the same complaint. One reader pointed out rhyming couplets in which the last words of each line wrapped onto a new line in the Jornada display; when the rhyming words drew attention to themselves, the verse gave the reader an unanticipated perception that it was doggerel. Re-reading the poetry on paper immediately corrected this misperception and the verse was restored. Figure 3 shows an example of this phenomenon.

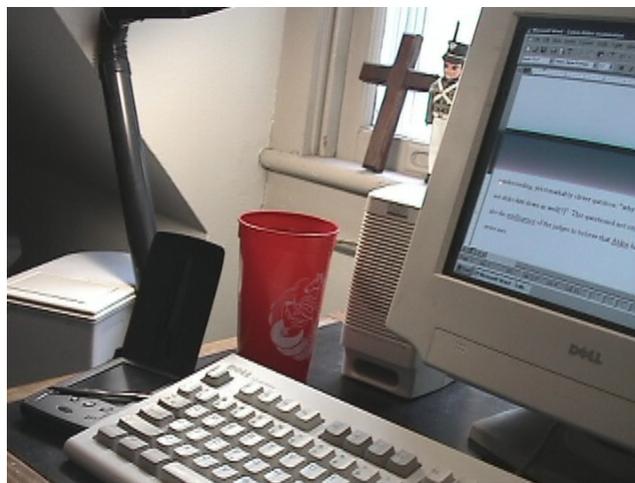


**Figure 3. Poetry is illustrative of a genre with strong layout sensitivity**

In general, portability tended to outweigh these problems when the texts were shorter, and reading was shallower, more for the purpose of familiarization with the text. One student who used the Jornada to some extent said:

"You get this little screen, so you get no sense of even how long the work is. How long an article is. You have 600 pages, which means what? No-one knows. And so ... I definitely don't see it as a literary experience. It's useful when you're traveling. It's useful when you're trying to read something that's in Special Collections and you don't want to go during their hours. As a supplement, but not as any kind of a primary tool."

The handheld's portability ultimately enabled the students to bring it with them to wherever they were working, and use it as an auxiliary display, much as Myers observed in [14]. Figure 4 shows an example of this configuration. The student used his Jornada as a source of quotes while he was typing a class assignment on his desktop computer and consulting his paper notebook and one of the primary texts (a paperback book).



**Figure 4. A student's Jornada is next to his home desktop computer. He is using it for quotes in a writing assignment. To the right of the computer (not visible in the picture) are his print book and paper notes.**

### 3.2 Choosing the Appropriate Format

From our discussion of the trade-offs, it is evident that the students explicitly chose among formats when they read the assigned materials and the other materials that were available in a multitude of electronic forms. For example, Dickens' *Bleak House* is available as an e-book, as Web-browseable HTML, and as a print paperback or hardbound book (in many editions). Additionally, the Web form of the book can be printed on free printers on campus, or on personal printers at home. Given all these choices, what did the students do?

In general, students, faculty, and Electronic Text Center staff members (in both classes) with few exceptions preferred to read shorter articles and excerpts and secondary materials for classes on their Jornadas. This finding holds for informational and entertainment reading as well (although a few have downloaded the longer novels offered by the Electronic Text Center). Some study participants downloaded periodical material (the *Onion*, the *New York Times*, news articles from Yahoo, and the like). The decision to read on the Jornada is highly contextual; one professor, disinclined to use the handheld in her office or the classroom when printed texts were ready to hand, reported using the Jornada with great satisfaction on a long plane trip.

The Pocket PCs were a sufficiently successful reading vehicle that some of the students wanted to download similar kinds of texts from their other classes. It is a notably common complaint that the e-books for sale on the Barnes and Noble or Amazon online stores are not what the participants in this project want to read; instead, they are more interested in the materials one might reasonably find in a university's well-stocked digital library (for example, the secondary readings for their courses, especially materials with limited access like reserve readings, readings from Special Collections, or readings on microforms) or a library's reading

room (for example, newspapers and periodicals), or the materials – excerpts, reprints, and other articles – that they might purchase as course packs.

On the other hand, the Jornada screen was adjudged by some as too small for approaching lengthy primary materials for class. Although these materials (like Dickens' *Bleak House*) were readily available, students chose to read them in paperback. The graduate students regarded these primary texts as archival (along with their notes on them), and wanted the physical artifacts. A few of the participants in this study did do some leisure reading of the Electronic Text Center books on their Jornadas, and were satisfied with the experience.

It was less common for students to print the Etext materials than we expected, given the students' access to the free printers on campus and their mobile reading habits. In fact, most of the students said that at the conclusion of a class, they threw away the printed course packs they had purchased, and that they felt a little guilty doing so. They would much rather have these paper documents distributed to them as digital readings, especially if the documents are relatively short. One of the undergraduates expressed a common sentiment:

"I'm kind of an environmentalist, so I'm happy that I don't have to throw away all those papers at the end of the year. It sort of kills me that I have to throw away those papers at the end of the year."

What else did the students print, if only a small segment of the longer digital library or class materials? They were more apt to print things they had produced themselves or other non-published materials that required more than a quick read, short documents that were necessary for reference, or papers that needed to be handled as tangible artifacts. When asked what she printed, a student replied:

"Mostly my documents. I rarely print things from the Etext Center for example. But I print all my own documents. My students all hand in their work by email, so I do print that, their things pretty often. I'll print a Web page if it's something I need, like a Ticket Master Web page or a Travelocity Web page. But mostly Word documents ... either by my students or me... and my students' ones are getting a little long, so I've been trying to do that in the computer labs."

One of the most interesting choices the students made was among digital formats. Would they read the digital materials prepared by the Electronic Text Center on their portable handhelds or on larger portable devices like laptops in MS Reader format? Or would they read in a Web browser on a desktop or laptop? It was not unusual for the students to choose among formats and reading venues according to exogenous factors such as the availability of specific search facilities. For example, many of the students opted out of MS Reader when they needed to search across texts (this was particularly true for some of the biography assignments in the religious studies course). Instead, the students used the search engine provided by the Etext Center and searched over the course materials to find biographical information spread across different texts. They might also read the materials the first time on the handheld, then write a paper using the version on the Web.

### 3.3 Collaboration

We generally think of reading as a solitary activity. But many of the readings were also used in in-class discussions, which brings

to light both problems and opportunities for the handhelds. In this section, we first discuss an interesting problem that may also be true for physical texts, that of creating shared reference to specific locations in the text, and how materials preparation affects how the readings can be used in class. We also discuss two interesting opportunities unique to digital library reading technologies: the opportunity to conduct serendipitous on-the-spot research using materials on the device as references; and the opportunity to imbue digital documents with some type of physicality. Finally, we provide some examples of how students learned how to use the Jornadas through interactions with each other.

#### *Creating shared reference to locations in the text*

Shared reference is a persistent problem, even given stable texts in printed editions. Because students may already own some of the texts from previous courses, a given shorter work may be part of many anthologies, and because the books may be purchased more cheaply secondhand, students bring a variety of editions to class. Add to this the physical/digital mix we observed in the classes in the study, and the classroom becomes a situation in which some versions will have line numbers and others won't, and in which page numbers aren't stable (due to text resizing and reflowing on digital devices). Thus shared reference within a text becomes a difficult exercise. During one discussion in the graduate class, for example, students were reading a poem from several different paper anthologies, a printout of the material from the Web, and from the Jornada.

In-class use of the Jornadas to access materials requires quick, easily communicated modes of navigation to establish shared reference: the ability to get to the same place in the electronic text on par or more quickly than in print text was vital to the handhelds' use in a collaborative setting. Interestingly, the undergraduate class made extensive use of the Jornada in class, while the graduate class did not. This may have had to do with the way the materials were structured: for the undergraduate class, in-class co-navigation was done using hypertext links from the table of contents; for the graduate class, everyone would use search to get to the right place in the longer texts. Using within-document search for this type of navigation was reported as too slow.

#### *On-the-spot use of references: bringing materials into the conversation*

The students (and faculty members) used the Jornadas for on the spot use of their reading materials as references. We observed this in the undergraduate class, and were told in interviews that it was not uncommon for participants to use the course materials in classroom conversation by looking up answers to specific questions on the Jornadas. For example, in an observed class session that covered Arthur Miller's *The Crucible*, attention was called to a prefatory remark about the hanging of two dogs at the Salem witch trials. The students immediately started looking for documentary evidence that such an event transpired. "Did they really hang dogs as witches?" To some extent the Jornadas freed the classes from the chronology mapped out by the syllabi; because the devices held the readings for the entire semester, the faculty and students were able to spontaneously refer to materials from any part of the syllabus. Several students told us that wireless access to online sources would make the experience even more compelling. This is comparable to our previous work with law students [13] and Jones et al.'s study of wireless tools in the library [9].

### *Reclaiming hand-to-hand physicality of paper documents*

When documents are physical objects, much meaning is conveyed by the way they are passed from person to person [7]. The students seemed to like the idea of using the IR port to hand documents to others as they would hand them person-to-person (in this case, to turn in assignments or pass notes among themselves). When we observed one student turning in her homework this way, she said, “I couldn’t get to the printer” (most of the students go to the library to print, but they use the Jornadas in a multitude of places). Thus the student was not viewing “beaming the document” as a substitute for handing it in via email, but rather as a substitute for handing in a paper document.

In spite of this observation, in practice the students revealed that it was more of an idea that engaged them rather than something that was in common use. Yet many of the students had tried the infrared connection and established that impractically close proximity was necessary to make it work. Beaming documents or notes occupies an interesting niche partway between the physical and the digital. Indeed, it is a way of passing an intangible digital document hand-to-hand.

### *Learning to use the handheld readers*

Like any sophisticated technology, the handhelds introduced some questions about what (and how much) the students would learn about the devices to make effective use of them in their day-to-day activities. Although the students showed some reluctance to come to the Electronic Text Center for formal training, they engaged in the type of over-the-shoulder learning that Crabtree et al. would predict [3]: students would show each other ways of using the functionality on the Jornadas. Some of the learning contributed directly to its use as a reading device; other learning had to do with the handhelds themselves (for instance, how to “beam” files to another handheld or how to download games). For example, one student said he’d learned to jump to a later page in an e-book from someone else in the class: “Somebody told me a few weeks after we got this [the Jornada]. Until then, I had to flip through.” Another student reported that:

“It was things like closing applications. No-one knew how to do that, and my boyfriend was playing with it. And he said, ‘You have seven different things open. You might want to close them.’ And so then I shared that with the class.”

### **3.4 Functionality in support of reading**

One of the opportunities offered by this deployment was to observe how reading-directed functionality – annotation, search, and other navigational features – were actually used in the students’ work. In this section, we focus on the two most used and useful kinds of functionality, annotation and search. We also note observations that would contribute to future design of this kind of functionality, especially for small form factor devices.

#### *Annotation*

Personal annotations are often highly task-specific (and many are writing-related, as we discuss in [13]). For example, students in this study and past studies describe making a post-reading pass over the text to identify quotes to use in writing. Most of these annotations (including those on paper) lose their value after the task is completed, although they may serve as a map to a partially read book. For example, one of the graduate students said:

“I was looking at *Biographia Literaria*, which I have in the paperback. And I actually meant to bring it today, so I could see what I underlined last time I read it. But I forgot it... And I was reading different sections anyway, because the last time ... I was reading it for a religion course. Undergraduate... So we were looking for different things in the text.”

Thus, in reflection, she thought her earlier annotations might not be useful in this context. Likewise, it is clear from student comments that while they sometimes like seeing their markings again, they might be of dubious value:

“Some of them [the annotations] are absolutely ridiculous and I can’t believe that I actually wrote this in pen in this book. Some of them are – I have no idea what I’m talking about. Some of them are really interesting, and it’s something I’d forgotten. It just depends on the notes. I had, when I did Milton, we were doing the epithets about Satan or something, so I underlined all of them. And when I was going back through it, I’m like ‘what on earth!’”

If the reading in question is simply for class and has no associated assignment, most students did not bother to annotate, especially on the handhelds. In general, all types of annotations (including bookmarks, notes, and highlights) on the Pocket PCs were infrequent.

Of the kinds of annotations students make on the screen, highlights were cited as the most important type. This is unsurprising, since the students generally reported either underlining or highlighting their textbooks far more frequently than writing marginalia; this finding was confirmed by looking through the students’ materials. One type of annotation the students make on paper that they noted as missing from MS Reader might be classified as ‘marks’ – asterisks, stars, or checks; they make these markings by passages they think are important or difficult. A combination of highlighting facilities and a simple vocabulary of marks might work especially well on the smaller devices. Students suggested several plausible enhancements to the annotation functionality, including the capacity to export annotations, to highlight across multiple pages, and to automatically capture (and perhaps dynamically update) cited page numbers in the annotation lists. The inability to export highlighted passages or text notes for use in writing papers was singled out as a particular disincentive to annotating on the Jornada.

As Wolfe hypothesized [18], the authority of in-class (and therefore expert) annotations makes them more valuable than the personal annotations the students make while they are reading. In fact, with few exceptions, the only kinds of annotations singled out as having lasting value were those made in class. Taken together with the limits on in-class use and on the annotation functionality appropriate for the handheld, it might be difficult to supplant this function of paper materials.

Pragmatically, if we are to think about the role of the handhelds for the students, we must consider note-taking as well as annotation; note-taking is universally described as key to memory. Most of the students report that they take separate notes on their reading in class or when they are writing papers. These notes are still written in paper notebooks with varying topical strategies (some students use spiral bound notebooks that they segregate by day, while others allocate one notebook per class). A few initially

tried to take notes on the Pocket PC during class, but all said that it couldn't keep up with their handwriting.

On the other hand, the students' reading notes may be taken on laptops (either borrowed from the library or their own); the same students would not bring a laptop to class for note-taking (it is considered rude and distracting). Thus solving the note-taking problem is a little more problematic because of the nature of the handhelds; some students felt that a plug-in keyboard (available for many pen handhelds) would be the solution for them.

### *Search*

Search facilities may be used in two fairly distinct ways in the kinds of reading we observed. First, it can be mainly navigational; it can enable the students to get to a desired place within a particular text or to locate a familiar document within a larger corpus of documents. This kind of search may take place in class, when writing, or to navigate for other reading purposes (for example, to find where to start a short reading session). Second, it can be used for research and textual analysis, a strategy in which the search results (to locate themes or facts) are interesting in and of themselves. Of course, these two functions aren't completely distinct, but they suggest slightly different requirements.

The first kind of search, as demonstrated in the transcript in Figure 2, often interacts with document structure. That is, if it is used for navigating to a desired place in the text, the student will probably need to back up to a structurally appropriate place to get sufficient context to begin reading. The search itself also may be constrained to a document substructure or range of substructures (look in the next chapter, for example). This type of search may also interact with existing annotations, particularly in a familiar document. That is, the student wants to return to a chapter she's read and marked in; the markings make it more likely that this is the passage she's looking for, such as a quote for use in a paper.

The second kind of search is more closely connected with textual analysis and research. One of the students described using the text on the Jornada to research an abstract question suggested by the professor:

"I was searching one of the things that [the professor] had suggested in an email ... Things to look for in the critical reading. And just one of the offhand things that she tossed off was, 'do they say anything about universals versus particulars?'... And that caught my interest. ... First I searched for 'particular' and he uses the word particular a lot. So, you know, like a 'particular theory', a 'particular couch,' whatever. And not in the sense that I'm looking for... So then I searched 'universals.' But with both of those, I wanted to search – I wanted to find approximate – so that it would come up with 'particular,' 'particulars,' 'particularity.' You know. 'Universal,' 'universals,' 'universality.'"

Of the two forms of search, the first is more vital for the handheld. Because the students carried the Pocket PCs everywhere with them and read in short sessions, locating the right place to begin reading, and quickly navigating to a sensible structural part of the text is a common need. Furthermore, as we discussed earlier, use in class among the heterogeneous selection of print editions and electronic devices depends on quickly locating a point of shared reference.

## 4. CONCLUSIONS

As a result of this technology intervention, we can characterize on-screen reading practices on the handhelds as converging on quick reading, skimming, and scanning to meet the needs of a highly time-constrained, highly-fragmented day. The ready portability of the small form factor devices offers such a decided advantage in supporting this type of reading that it compensates for the reduced display space. We also learned that the structure of the electronic materials and the navigation afforded by this structure in conjunction with the appropriate functionality (such as search and hypertext links) had a profound impact on how (and whether) the handhelds were used, both individually and in a classroom situation.

Given our experiences, we would recommend that similar efforts:

**Focus on shorter materials that are less format-sensitive and on materials that are difficult for the students to access in print form.** This recommendation especially pertains to readings that are distributed right now as photocopies or electronic files, or are special holdings that are in rare book collections, on microforms, or must be placed on reserve reading. Course packs are a possible model for the kinds of digital library materials that may be distributed on handhelds. In this way, the materials offered on the handhelds do not compete with print or "big screen" offerings, but rather exist in an ecology with them. Care must be taken to balance compact materials with sufficient context in which to interpret them, as Bishop has observed in her past work on the effects of disaggregation [2].

**Focus on ways of promoting structural markup and manageable documents.** Some of the electronic documents used in this technology deployment were broken up into more manageable chunks and marked up in such a way that they had a very good, very complete (but not unmanageably long) Table of Contents. Thus the materials themselves reflected the students' preference for shorter documents and good ways of navigating through them.

**Focus on functionality like good search and navigation, along with very simple annotation mechanisms.** Search is key to three reading-related activities -- for research (getting the materials to read in the first place), for finding familiar materials (getting back to the materials one has already seen), and for within-document navigation (getting to the right place to read in longer materials). Each form of search may pose different requirements. Search may be done individually or collaboratively (in class). Records of reading (like annotations) may be fundamental in forming a personal geography of the electronic work. Thus, it is important to be able to highlight or underline through direct interaction with the text. Marginalia is less important for this kind of reading and form factor. On the other hand, it is important to be able to display and use annotations made on other digital devices.

**Focus on the way documents may be passed around.** This hand-to-hand (i.e. handheld-to-handheld) movement of documents and reading materials is an important hybrid of paper and electronic practice. If published materials are involved, this may specify new digital rights management needs.

Some important issues remain for future investigation. The first involves getting materials onto the device. In our deployment situation, the students were given the handhelds with the materials and reading software already on them. Such an investigation would entail instructing the students and faculty members on how

to download new materials, and how to prepare ad hoc documents in appropriate formats for use on the device.

The second has to do with the conceptual picture that the handheld presents: is it an e-book (a vehicle for reading an electronic book), an e-case (an electronic briefcase that holds all the digital materials a student need to haul around in the course of a day), or a personal digital library, held and maintained over long-term use (a role Lynch advocates in [11]). In this initial study, the students had varying interpretations of the role of the handhelds; each point of view was represented.

Finally, it is important to understand the potential for the use of the Jornadas in the collaborative situation of the classroom. On one hand, they have enormous potential for facilitating new kinds of exploratory in-class discussion, and they are not nearly as obtrusive as laptops or the full-size monitors in computer classrooms or labs. On the other hand, it is easy to see how they promote divided attention; students readily admitted to doing a variety of things (for example, playing solitaire or reading for one class in another) that had nothing to do with matters at hand.

**In general, the success of introducing an electronic reading platform like the Jornadas relies on the ability to think of reading as a hybrid activity.** The notion of surrounding oneself with one's source materials is ubiquitous. People do focus on a single reading surface or display at times, but then they bring it into a broader context. Students used their handhelds with paper books, full-sized displays, print documents, and with each other. Reading is an unselfconscious orchestration of many things; successful introduction of digital library reading technologies like the Jornadas depends on seeing their role in a larger system of documents, technologies, and reading-related activities.

## 5. ACKNOWLEDGMENTS

We thank the study participants, including the students and faculty members who made the deployment possible. We also thank the Electronic Text Center staff, especially its director, David Seaman, and the Microsoft eBooks group (especially Susanne Peterson) for supporting the study.

## 6. REFERENCES

- [1] Adler, A., Gujar, A., Harrison, B., O'Hara K. and Sellen, A. A diary study of work-related reading: design implications for digital reading devices. In *Proceedings of CHI98* (Los Angeles, CA, April 1998), ACM Press, 241-248.
- [2] Bishop, A. P. Digital libraries and knowledge disaggregation: the use of journal article components. In *Proceedings of ACM DL '98* (Pittsburgh, PA, June 1998), ACM Press, 29-39.
- [3] Crabtree, A., Twidale, M.B. O'Brien, J. & Nichols, D.M. Talking in the Library: Implications for the Design of Digital Libraries. In *Proceedings of ACM Digital Libraries '97* (Philadelphia, PA, July 1997), ACM Press, 221-228.
- [4] Dillon, A. Reading from paper versus screens: a critical review of the empirical literature. *Ergonomics* 35, 10 (1992), 1297-1326.
- [5] Gibson, M. and Ruotolo, C. Beyond the Web: TEI and the Ebook Revolution. *Proceedings of ACH'01*. Online [http://www.nyu.edu/its/humanities/ach\\_allc2001/papers/gibson/index.html](http://www.nyu.edu/its/humanities/ach_allc2001/papers/gibson/index.html).
- [6] goReader site. <http://www.goreader.com/index.htm>.
- [7] Harper, R. and Sellen, A. Collaborative Tools and the Practicalities of Professional Work at the International Monetary Fund. In *Proceedings of CHI '95*. ACM Press, New York, 122-129.
- [8] Inkpen, Kori M. Designing Handheld Technologies for Kids. *Personal Technologies Journal* 3, 1&2 (1999), 81-89.
- [9] Jones, M., Rieger, R., Treadwell, P. and Gay, G. Live from the stacks: user feedback on mobile computers and wireless tools for library patrons. *Proceedings of ACM Digital Libraries 2000* (San Antonio, TX, June 2000), ACM Press, 95-102.
- [10] Levy, D. and Marshall, C.C. Going Digital: A Look at Assumptions Underlying Digital Libraries. *Communications of the ACM* 38, 4 (April 1995), 77-84.
- [11] Lynch, C. The Battle to Define the Future of the Book in the Digital World. *First Monday: A Peer-Reviewed Journal on the Internet* 6, 6 (June 2001). Online at [http://www.firstmonday.dk/issues/issue6\\_6/lynch/index.html](http://www.firstmonday.dk/issues/issue6_6/lynch/index.html)
- [12] Marshall, C.C., Price, M.N., Golovchinsky, G., and Schilit, B.N. Introducing a digital library reading appliance into a reading group. In *Proceedings of ACM Digital Libraries '99* (Berkeley, CA, August 1999) ACM Press, 77-84.
- [13] Marshall, C.C., Price, M.N., Golovchinsky, G., Schilit, B.N. Designing e-books for legal research. *Proceedings of JCDL 2001* (Roanoke, VA, June 2001), ACM Press, 41-48.
- [14] Myers, B. Using handhelds and PCs together. *Communications of the ACM* 44, 11 (November 2001), 34-41.
- [15] OEBF. Open eBook™ Publication Structure 1.0 specification. Open eBook Forum (1999). Available on the Web at <http://www.openebook.org/OEB1.html>.
- [16] O'Hara, K., Smith, F., Newman, W., & Sellen, A. Student Readers' Use of Library Documents. in *Proceedings of CHI '98*, ACM Press, 233 – 240.
- [17] Schilit, B.N., Golovchinsky, G., and Price, M.N. Beyond Paper: Supporting Active Reading with Free Form Digital Ink Annotations. In *Proceedings of CHI98*, New York: ACM Press, 217-226.
- [18] Wolfe, J. Effects of annotations on student readers and writers. In *Proceedings of ACM DL 2000* (San Antonio, TX, June 2000) ACM Press, 19-26.