Chapter 18

Using Handheld, Wireless Computers to Increase Interactivity and Collaborative Learning in Large Classes

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Introduction

As undergraduate enrollment spirals upward, we are faced with increasingly larger lecture audiences, especially in introductory courses. Such large courses are notorious for promoting disinterest and low motivation among students. The use of wireless computing offers ways to combat these problems by creating opportunities for students to become actively involved in learning while in the classroom, and by providing easy access to course materials outside of class.

Our goal was to find a way to increase interaction between faculty and students and groups of students in a traditional lecture format. We obtained funds from the University of North Carolina consortium and our University's Learning Technology Services to test the effectiveness of handheld computers to increase motivation and encourage collaborative learning in the classroom. We compared the capabilities of the largest type of handheld, the Jornada 820 "mini-laptop," to that of the smallest, a Handspring Visor "personal digital assistant." Two classes participated in the pilot study: a senior-level course in evolution, and a two-semester junior/senior level course in developmental anatomy and histology. The methodology is equally appropriate for introductory

biology, and within two years, we plan to introduce handheld computers into a wide range of courses within the College of Agriculture and Life Sciences. In this article, we share our findings on the benefits vs. disadvantages of both types of handheld computer and discuss what did and did not work from the viewpoint of both students and instructors.

Materials and Notes for Instructor

The Jornada 820 and Apple Airport
Hardware

We chose the Jornada 820 because its light weight (2.5 pounds), large color screen (640 x 480 pixels), and keyboard provided the basic capabilities of a laptop computer plus better portability at a low cost (Figure 1). We purchased 14 Jornada 820 computers from Hewlett-Packard at a cost of $628 (US) each and added 16 MB of RAM for a total of 32 MB. The additional RAM proved crucial, since unlike conventional laptops, the Jornada lacks a hard drive, and all applications and data are stored in available memory. The 820 came with a Compact Flash slot, VGA port, and USB port, as well as a standard PCMCIA slot. Compact flash 8 MB cards were

Figure 1. The Jornada 820 computer and Apple Airport. The Jornada 820 is a mini-laptop computer with a large screen and a keyboard. It can access the internet via a wireless networking card (arrow) when a base station (the Airport) is connected to an ethernet port.

purchased from Microwarehouse and proved quite useful for transferring files between students and instructor. The VGA port was used to connect the Jornada to a classroom projector during exercises requiring student presentations. The PCMCIA slot allows use of a standard wireless networking card, as long as the manufacturer has drivers for the Windows CE operating system and supports the Jornada's CPU type. We purchased Lucent (now Orinoco) Silver PCMCIA cards that shipped with Windows CE drivers that work with the Jornada.

For internet access in the classroom, we used the 802.11b wireless standard. This technology has emerged as the *de facto* standard for wireless network access for laptop and desktop computers. We chose Airport base stations (Apple Computing) as our wireless access points (Figure 1). Apple's Airport technology, co-developed with Lucent technologies, was the first to make wireless networking a consumer product. One Airport base station was installed in each of our classrooms and connected to the ethernet port within the room. An Airport can accommodate up to 20 simultaneous users for each Airport base station, and we had no problem with 14 users per station. Large lecture halls will require additional base stations. Wireless access points typically are advertised as having an open range (no walls or obstructions) of about 300 feet, which at once is a blessing and a curse. In a large lecture hall, where multiple wireless access points might be deployed, some care may need to be taken to maximize coverage while effectively distributing the network load on each access point.

We configured our Apple Airports with a fixed IP address, and then allowed the Airport to distribute IP addresses to the Jornadas using DHCP. Therefore, very little configuration had to be done on the Jornadas themselves. While it is possible to configure Apple's access point with a Windows machine (using software such as the open source FreeBase), we used Apple's own Airport administration software on an Apple Powerbook. Some vendors now include web based configuration for their 802.11b access points, which means that any computer with an internet connection and web browser can configure a wireless access point; a very handy feature.

Software

The Jornada 820 shipped with Windows CE 2.11 installed (newer versions of the CE operating system are now available), as well as Microsoft Explorer for Windows CE, and Microsoft Pocket versions of Word, Excel, and PowerPoint. The Windows CE operating system is similar to Windows 95 and thus familiar to most users. The web browser supports key features such as SSL, Cookies, and JavaScript, but does not allow web pages to be edited or PDF files to be displayed. Pocket Word allows basic word processing similar to Microsoft Word, but with limitations. Instructors must be aware that this familiar-looking application is not identical to Microsoft Word and that its capabilities vary depending on the specific version of the Windows CE or Windows Pocket PC operating system. For example, Pocket Word on the Jornada 820 does not allow graphics to be inserted into text documents, whereas the version packaged with the Compaq iPaq handheld does support this function. Similarly, the formatting of a Microsoft Word document produced on a desktop computer may not be faithfully reproduced on the Jornada. Another limitation of the Jornada is that it interfaces with PC, but not Macintosh computers. As Macintosh users, we were annoyed at being forced to install applications from a PC laptop running Windows 98 and Microsoft's ActiveSync software. However, Compact Flash cards may be effectively used to transfer text or image files from a Macintosh (equipped with a Flash Card reader) to the Jornada. In fact, Microsoft Word documents transferred via Compact Flash cards are converted automatically into Pocket Word documents viewable on the Jornada and editable from the Flash cards. To work with images, we purchased Pocket Artist (Pocketgear). Given its small size, this application has an impressive set of features that allow both viewing and editing of images in BMP, GIF, or JPG format. Graphics can be transferred from desktop computers to the Jornada via Compact Flash cards or with Microsoft's Activesync software.

The Handspring Visor

Hardware

For our smallest handheld computer, we chose the Handspring Visor Deluxe, which utilizes the Palm operating system (Figure 2). The original Palm Pilot was a breakthrough in that it took an approach offered by other, more expensive PDA's (such as the Newton) and scaled down cost, features, and size to something that was useful and affordable. It helped make the term "PDA" a recognizable part of our language. Palm Computing has chosen to license their operating system to other companies, and Handspring is one of those companies. We selected the Visor because its slot for interchangeable modules provided the potential for many additional functions, including wireless internet access. The Visor Deluxe was the cheapest model that provided 8 MB of RAM ($250 US at time of purchase). We added 8 MB memory expansion modules to provide additional space for storing course materials in the form of hyperlinked text documents with embedded graphics. While the Jornada resembles a laptop, with it's nearly full sized keyboard, the Visor relies primarily on handwritten input, using a block letter scheme called Graffiti writing. With a total 16 MB of RAM and a black-and-white 160x160 pixel

screen, the Visor proved adequate for classroom use, but presented challenges in the types of content that could be utilized.

The Visor is a small handheld computer (PDA), which uses the Palm operating system. Text or numbers may be entered by printing them with a stylus on the lower portion of the screen. We installed iSilo and FireViewer to supplement the preinstalled applications (icons visible on Visor screen).

We had planned to use the Handspring expansion slot for a promised 802.11b compliant

Figure 2. The Handspring Visor Deluxe.

wireless module (Xircom), but delays in shipping forestalled our use of wireless technology during the pilot project. We have now received a Xircom module and tested it on both the Visor Deluxe and newer Visor models. The module is not completely reliable in the Visor Deluxe, but it works well with models containing a newer version of the Palm OS (version 3.52 vs. 3.1). The Xircom module has it's own internal rechargeable battery which extends battery life of the handheld when used for wireless internet access. The module also contains a small amount of flash RAM, including preinstalled applications: a configuration tool, a web browser (Blazer), and a mail client (Multimail).

Having deployed 25 Visors to students for the duration of the semester, we needed a simple way to configure them identically, including categorizing the extensive course materials stored in each unit. To that end, we created 25 accounts on a desktop computer reserved for our use in a student computer room, set up one handspring the way we wanted it to be, and hotsynced (synchronized content) with the desktop computer. We then copied the necessary data from the hotsynced handspring's directory to the other 24 accounts on the PC, in their respective "install" directories. After all Visors had been hotsynced, their contents were identical. This approach meant that we could easily restore a Visor that had lost it's content (if by chance the batteries had run out, and the student had ignored the warnings) by hotsyncing with the same PC. We have now simplified the process by using a backup module. It is designed to provide a simple way for users to back up their Visor, but we used it to replicate the configuration of the Visor. After backing up the properly configured Visor, we then placed the module in each Visor and used the "restore" function to configure all Visors alike. The only undesirable effect is that all units now have the same user name attached to them. Fortunately, we have found an undocumented feature that allows us to remove the user name. The PC with 25 Visor accounts was also used to load new material into the Visors during the course. We simply placed the new items into each account and asked the students to stop by the computer room for a quick hotsync.

Software

The Handspring Visor uses Palm desktop software to install applications, and contains the same essential functionality (date book, notes, etc.) on both the handheld itself and in the desktop software. The software is available for both the Windows and Macintosh platforms, which made it easy for us to install applications using the supplied cradle connected to the USB port of our desktop
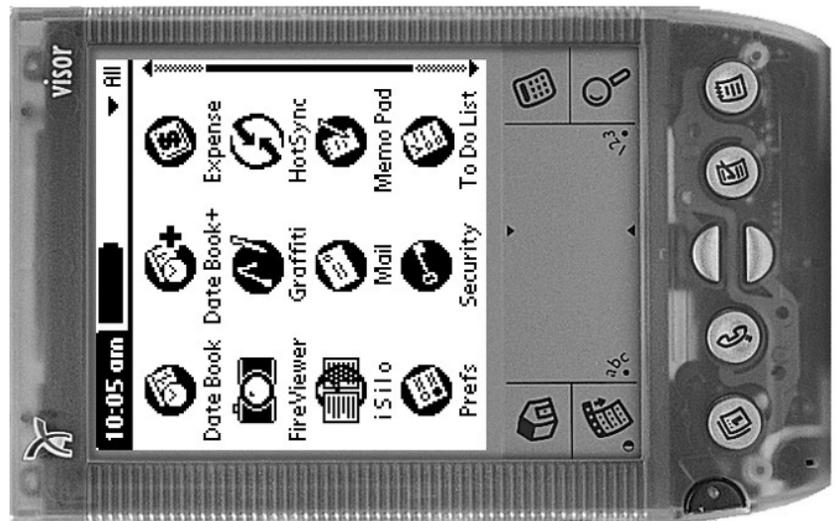
computer. Handspring sells a serial port cradle separately, if one is needed. We installed several additional applications on the Visors, including iSilo, FireViewer, and TealPaint (Table 1). iSilo is a document reader which allows any document originally in text or html format to be viewed in the handheld. The application comes with software that runs on PC or Macintosh computers to convert documents into the proper format for viewing in iSilo. Converted documents are then loaded into the Visor via the cradle. For html documents, the converter software follows hyperlinks (to any depth desired), and includes all linked pages and embedded images with the document. When viewed within the handheld, links work and graphics are visible, although the latter are of low quality and may require both horizontal and vertical scrolling to view the entire image. FireViewer is a very nice image viewer that presents graphics in color or 16 levels of gray scale and allows the user to organize and annotate images. Images may be converted to the required PDA format by purchasing the FireViewer converter or via GraphicConverter (Lemke, Inc.). TealPaint is a simple draw/paint program that can be used to create drawings or to edit imported images. Images in BMP format are loaded into the Visor by software that is included for the PC or downloaded from a shareware web site for the Macintosh.

Table 1. Useful web sites for information on handheld computers, software, and accessories.

Web sites for useful products	Products of interest
Handhelds using the Palm Os	
http://www.palm.com	Palm Computers
http://www.handspring.com	Handspring Visor computers
http://www.handera.com	Handera Palm-type computers
http://www.sony.com/clie	Sony Clie Palm-type computers
Handhelds using Windows Systems	
http://www.microsoft.com/windowsce/	Windows based handheld computers
http://www.hp.com/jornada	Hewlett-Packard mini-laptop computers
http://www.neccomp.com/	NEC mini-laptop computers
http://www.compaq.com/showroom/ handhelds.html	The iPaq and other Compaq handheld computers
Software and accessories for handheld computers	
http://www.palmgear.com	Large selection of Palm software
http://www.handango.com	Large selection of Palm software
http://www.fireviewer.com	FireViewer application and converter
http://www.tealpoint.com	TealPaint application
http://www.isilo.com	iSilo application
http://www.apple.com	Apple airport and computers
http://www.mobileplanet.com	Handheld accessories (including RAM)
http://www.xircom.com/	Wireless internet access modules
http://www.pocketgear.com	Pocket Artist; Windows CE applications
http://www.ansyr.com/products/	PDF reader for Windows CE handhelds
http://www2.warehouse.com/	Lucent cards; Compact Flash products
http://www.avantgo.com	Web browser for handhelds with automatic downloading of web pages
http://www2.ncsu.edu/misc/mobile	**The NCSU mobile computing web site**

Student Use of Computers

Activities in the Classroom

Students had access to handheld computers during class in both classes participating in the pilot study (Figure 3). In the fall semester, pairs of students in Evolution shared a Jornada in and outside of class, whereas half of the students in Developmental Anatomy and Histology were assigned a Visor for the semester and allowed to take it home. All students were expected to bring their handheld to class meetings. We anticipated that students might take notes on their handheld during classroom lectures (using Pocket Word in the Jornadas or the memo pad in the Visors), but this did not occur to a significant extent. Some students did use their handheld to follow the lecture by accessing the course web site via the internet (Jornadas) or from the stored course outlines and images (Visors). Students expressed a desire to annotate the course web pages and outlines during lecture, as opposed to taking lengthy notes, but we were unable to find software that allowed comments to be written directly on Explorer or iSilo pages. Our main goal however, was to increase interactivity in the classroom and to engage students in the learning process in a non-intimidating atmosphere. To this end, we devised several types of exercises in which students utilized their computers while working in pairs or small groups.

Figure 3. Students using handheld computers in class.
A) Jornadas in Evolution, B) Visors in Developmental Anatomy and Histology.

Analysis of literature

In evolutionary biology, more than other disciplines, theory dictates research, and most empirical work is justified on theory testing. Exercises in Evolution were designed to increase student understanding of current controversies by analysis of primary and secondary literature. The original plan was to place articles in the library e-reserve web site for student access during class. Student groups would critique assigned portions of longer papers or several shorter papers and subsequently exchange insights gained from the experience. An initial problem emerged when we realized that the Windows CE version of Explorer would not display PDF files (the format in which our library stores digital reserve materials). We were forced to provide photocopies or to translate the PDF files into html documents, which the Jornada browser handled quite nicely via wireless internet access. The students preferred the html documents over photocopied articles, since they could easily scroll to a portion referenced by students leading the discussion of a paper and could copy portions of downloaded pages into Pocket Word for future reference and annotation. However, our library does not provide documents in html format, and the process of converting PDF to html or scanning documents into html directly (via library equipment) proved quite time consuming. Available software produces errors during the conversion to html that must be corrected by manually

editing each article. We have recently located a PDF reader for the Jornada (Primer 3.1, Ansyr Technology) that allows PDF files to be downloaded from the internet, and even provides an annotating function via digital "sticky notes." Unfortunately, the reader scrolls through articles very slowly, especially when the PDF file is large or contains images. Thus, the html solution remains preferable, although very labor intensive.

In all cases of literature analysis, the students recorded their group insights electronically and presented them orally during the latter part of the class period. The recorded comments and summaries were gathered by the instructor via infrared beaming or Compact Flash cards and uploaded to the course web site after class. In a sense, students interactively and efficiently created their own notes and study guides regarding analysis of primary literature. We insisted that the role of "recorder" within a group rotate, and that all group members speak within a given timeframe. In the end, individuals ended up tackling different portions of a paper and exchanged Jornadas quickly as they alternated speaking and recording duties within their group. Students became determined to anticipate questions that could be posed by other students or the instructor regarding their paper during class discussions, and often incorporated such into their presentations. In this way, they tested each other on mastery of the material while working in the group.

Presentation with graphics

In Developmental Anatomy and Histology, much learning is visual and graphics are heavily utilized. During the Spring semester of this course, Jornadas were used during one class period per week to enhance student active learning and collaboration with emphasis on images. In one type of exercise, student pairs checked out Flash Cards upon arriving in class. Each card contained a different anatomy or embryology image (appropriate the topic currently under study) with an accompanying question or directive for the students to consider (Figure 4). After

Figure 4. The Jornada screen showing an image viewed in Pocket Artist. Students manipulated images for class presentations.

15 minutes, each student pair was required to give a brief presentation to the class that addressed the question and utilized the image as a visual aid. The students viewed their images in Pocket Artist and used this application to add labels or arrows to facilitate their planned talk. Presentations were given from the Flash cards by inserting them into the instructor's Jornada, which was attached to the classroom projector. Most students gave thoughtful presentations that often included impromptu drawing on the image via Pocket Artist to emphasize a point.
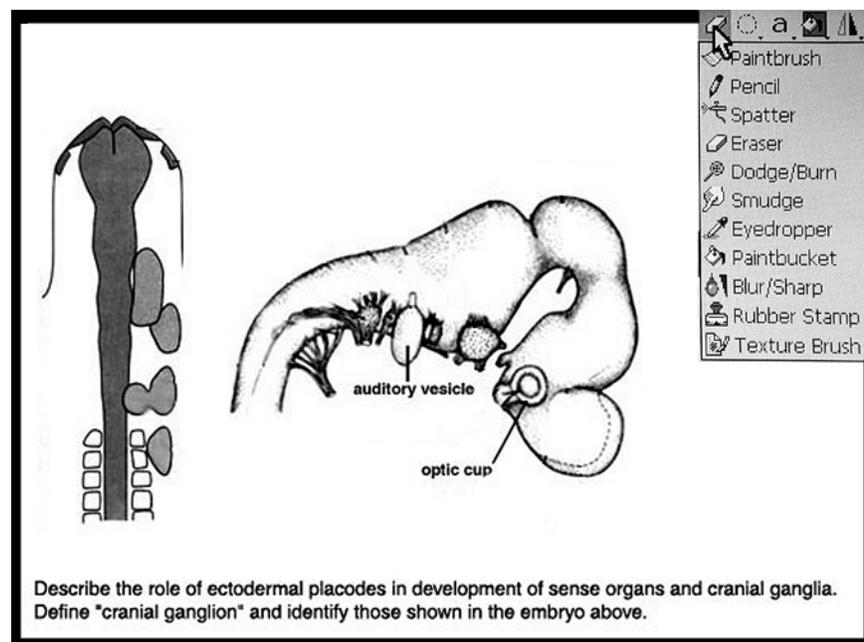
Writing assignments

A second type of exercise required student pairs to write a short essay during class on a topic posed by the instructor. The instructor's question typically involved one or more images viewed by students on their Jornada from a web site. One member of each student pair recorded the essay on a web form, which allowed the text to be sent immediately to the instructor's e-mail via wireless internet access. During the latter half of the class period, the instructor selected one or two of the essays from web mail and displayed them on the computer projection system. This led to class discussion of points included or omitted from the essay. Although the students disliked this exercise, it did seem to clarify their understanding of key concepts and (in at least some cases) enhance their writing skills.

Quizzing with feedback

A final exercise with the Jornadas utilized "instant feedback" quizzing to engage students during lecture-based teaching. Upon arriving in class, student pairs accessed a five-question, multiple-choice quiz from a designated web site. We used WebAssign, a homework submission and testing tool developed at NCSU, to design and administer quizzes. This program allows the use of images, supports a variety of question formats, and records quiz results on an instructor's web site, which can be displayed in the form of a class histogram and/or graded for individual students. After 10-15 minutes, student pairs were required to submit their quiz answers, which were recorded automatically by WebAssign. The instructor then displayed histograms of class answers to each question using the computer projection system (Figure 5). The students were quite interested in the class response to questions, and the results were used to elicit discussion on why a certain answer was right or wrong. In cases where most students gave incorrect answers to a question, the instructor could

Figure 5. Histogram of class response to quiz questions. WebAssign, a program developed at NCSU, was used to administer quizzes and display histograms of class response.

switch to materials on the course web site to elucidate points which had caused confusion. Fill-in-the-blank questions were also used in this way, but proved less effective in eliciting class discussion. This type of exercise was popular with students and engaged their attention during subsequent lecture on topics related to quiz questions. In the future, we intend to intersperse quiz questions with "instant feedback" during lecture on days when collaborative exercises are not planned. To this end, Dr. Henry Schaffer (Professor of Genetics and Biomathematics at NCSU) has written a simple multiple-choice quizzing and "polling" program that works well on both types of handheld computer.
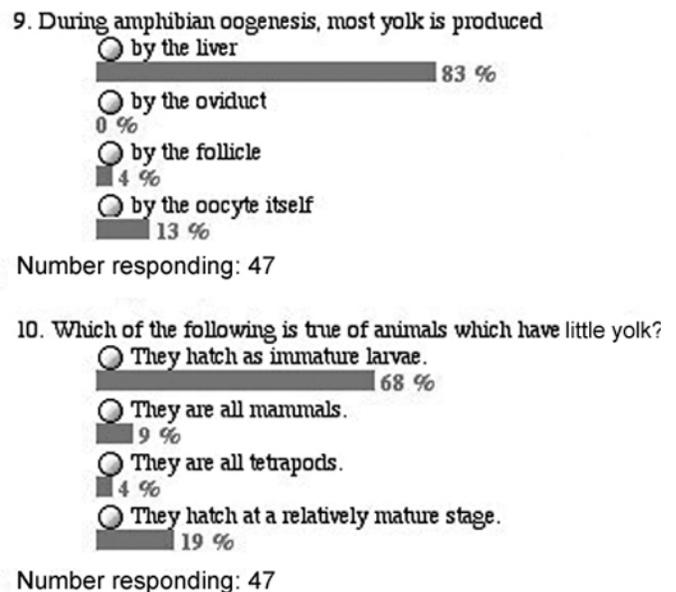
Use of Visors

Use of Visors during the pilot study was limited, since wireless internet access was not yet available. Three short exercises utilizing images were tried to ascertain the usefulness of the handhelds in the absence of internet capability. Images or tables in image format were loaded into Visors by requiring the students to hotsync their Visor with the designated PC before class. The classroom exercise required students to label the image or to fill in the table using information learned in previous studies (Figure 6). The instructor then showed a duplicate of the image or table via the classroom projector and elicited discussion regarding appropriate labels. Although the technology worked as planned, the pedagogy suffered from inability to display student work to the class. Use of the new wireless modules should correct this problem and will allow essay writing and quizzing to proceed as described for the Jornadas.
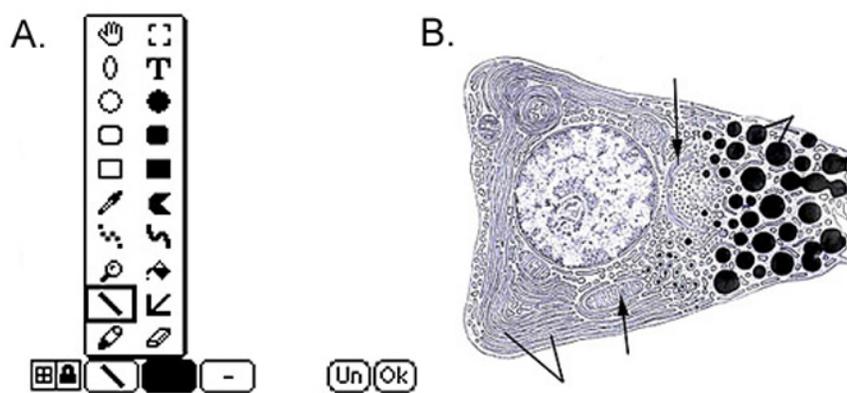

Figure 6. An image to be labeled using TealPaint. In a class exercise using Visors, simple graphics were loaded into the handhelds by hotsyncing and displayed by the application TealPaint. Students used TealPaint drawing tools to label the image. A) Visor screen displaying TealPaint tools, B) Image of a cell to be loaded into Visors.

Activities Outside of Class

Student pairs in the Evolution class were also allowed to "share" a Jornada outside of class. We hoped that students would wirelessly search web sites between classes for material to be used in two required presentations in which groups of students examined in detail some evolutionary topic not covered during class. We also expected students to assemble and deliver their presentations using Jornadas. Students were responsible for producing all materials for the presentations, including notes and potential exam questions to be studied by classmates. Students did meet in groups outside of class to surf the web and exchange appropriate URLs. This generally occurred in the library where a wireless access point has been installed. Problems were encountered, however, when we discovered that the Jornada PowerPoint program is only a viewer and does not allow composition of a slideshow. Since Pocket Word does not support graphics, the Jornadas had no program capable of combining text and images into a coherent presentation. Thus, the student groups opted to use the Jornada only for compiling a list of useful web sites and each group member constructed their portion of the presentation on a desktop computer. The entire presentation was then uploaded to the personal web space of one group member and presented from the web via the classroom projector.

Wireless web surfing was the feature whose potential was most valued by the students (see Assessment section). Although lack of wireless access points outside of class limited this activity and might have dampened student enthusiasm, students did realize the potential of wireless handhelds in interacting with the internet. Students envision a future in which they can at any time

and any place on campus, access email, e-reserves, and course material form the web "as easy as it is to make a cell phone call now."

Visors were in the hands of Developmental Anatomy and Histology students outside of class, but no assignments were given which required their use. We wished to determine what the students would do with their handhelds without directives from the instructor. Some students used the Visors to store personal information (phone numbers, date book, memos), but this usage was limited since students were not given cradles to hotsync with their personal computers, and because they had to return the Visors at the end of the semester. Some students did use the Visors to study the stored course materials outside of class. Since the Visors contained the entire course web site (with the exception of some images), students could access the material just as if connected to the internet (Figure 7). The small screen size and lack of color made some images difficult to discern, but most students found the text quite readable and useful for study.
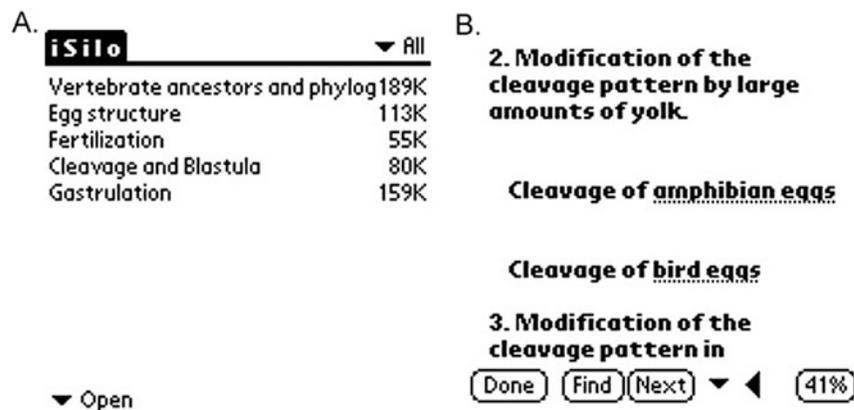

Figure 7. Visor screens showing course material viewed in iSilo. Course outlines from the web site of Developmental Anatomy and Histology were loaded into Visors using the application iSilo. This application allows topics to be categorized and supports functional links (the underlined words). A) Course topics displayed as a list by iSilo, B) Part of the outline on "Egg Structure."

Assessment of the Pilot Study

Evaluation of Jornada usage

Questionnaires were administered to the students in the Evolution class to survey their responses to the active learning exercises enabled by the Jornada (Table 2). Focus groups involving the entire class at the end of the semester, and casual interviews with about 1/3 of the students 3-4 months later, dealt with interpretation of questionnaire responses and students' general attitude toward the handheld computing experience. Focus groups were organized by Learning Technology Services personnel and convened in the absence of the course instructors. Students responded positively with regard to the instructor's pedagogical goals. On the questionnaire, students indicated that all types of interactivity increased except direct assistance to other students. Interviews revealed that this increase in collaborative discussion and exchange of ideas occurred outside as well as within the classroom. Interestingly, students did not interpret these interactions as assistance to other students or even "studying" with other students. Interviews revealed that students interpreted "assistance" as simply giving another student needed answers, which they did not do in this class.

Table 2.   Summary of answers from a Pre (first day of class) and Post (last day of class) questionnaire distributed to students in the Evolution course.

"Pre" responses are based on experience in other classes, and are listed below in regular font. "Post" responses are based on this class, and are listed below in bold font.
How often do you....

	Frequently	Sometimes	Rarely or never
Study with other students	6 / **8**	11 /**11**	5 / **2**
Work on assignments in group	5 /**14**	14 / **4**	3 / **3**
Discuss course ideas and concepts with other students	9 / **13**	11 / **7**	2 / **1**
Discuss with other students course related comments they made in class	3 / **0**	8 / **8**	10 / **7**
Assist other students	3 / **3**	18 /**13**	1 / **5**

"Pre" responses are from other science lecture courses. "Post" responses are based on this class, and are listed below in bold font.
How many hours per week did you.....

	0	1-2	3-4	5-6	7-8	>9 or 9-10 in post
Searching the web	6 / **1**	10 /**13**	4 /**4**	1/**2**		/**1**
Word processing	2 /**11**	10 / **8**	7 /**1**	1/**2**		1/
Using other application	5 /**11**	11/**7**	3/	1/		
Communication on line	10 /**12**	7/ **5**	2 /**1**	1/ **2**		
Creating web	18 /**22**	3 /**2**				
Studying.	1/	2/**12**	6 / **2**	7/**3**	/**3**	2/**2**

"Pre" responses are from the start of the course. "Post" responses are from the end of the course, and are listed below in bold font.
Please rate your preference for the following resources and activities.

	Most worth-while	Worth-while	OK	Less worth-while	Least worth-while	Don't know
Textbooks	1 /**1**	12 /**11**	8 / **7**	/**1**	1/**1**	
Instruct created study materials	16 /**17**	5 / **4**	1/			
Course pack	7 / **3**	11/**6**	1 /**2**	1/ **3**		5/
Handheld with notes preloaded	5/	2 /**4**	3/ **8**	3 /**3**	1 /**6**	6/**1**
Class time for small group discussion	3/**4**	7 /**12**	9/**1**	1/**3**	2/**1**	
E reserves		2/**3**	7 /**3**	4 / **6**	7/ **5**	2 / **2**

"Pre" responses are from this course. "Post" responses are from future courses, and are listed below in bold font.
Please indicate the degree you agree with the following statements.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I am ambivalent about using a handheld in future courses	1/	3 /**4**	15 /**11**	3 /**1**	1 /**2**
I am excited about using a handheld in future courses		6 /**1**	9 /**7**	/**10**	/**1**
I am wary about using a handheld		5/**7**	9/**10**	3/**1**	5/**1**

"Pre" responses indicate what they expected; "Post" responses indicate what they found, and are listed below in bold font.

How useful did you expect / find a PDA to be for.....

	Highly useful	Useful	Neutral	Not too useful	Not at all useful
Providing feedback to lecturer	3/	12 /3	5 /5	1/5	/7
Exchanging info with classmates	6/	9 /1	6 /6	/8	/5
Jotting down notes	2/	8/2	6/3	6/9	/6
Surfing the web on campus	14 / 5	5/8	3/4	2/	/1
Surfing the web off campus	7/	8/	4/5	3/2	/13
Transferring info to a personal web site	1	9/1	9/9	1/3	2/7
Making class presentation	5/	12/2	5/7	/4	/7
Doing homework	6/	12/3	3/7	1/2	/7
Viewing graphics	10/4	10/5	2/3	/3	/5
Keeping schedules	3/	9/3	6/6	2/5	1/6
Editing graphics	5/	7/1	7 /6	1/5	2/8

Increases were also noted in students' desire for small group discussion. We at first were disappointed that students did not regard this activity as a primary learning tool. However, interviews revealed that students answered this question, and others regarding resources, as pertaining to any course they had taken or planned to take. Thus, they continued to place higher value on study aids available outside of class such as textbooks, instructor created study materials, and course packs.

The one pedagogical goal that we failed to achieve was increase in student use of library digital reserves and appreciation of the library as a valuable resource. Since the Jornada could not display PDF files (the only e-reserve format), students could not access e-reserves during class or wirelessly outside of the classroom. Although we have recently installed a PDF reader, downloading the files is lengthy, and since the e-reserve files are PDF images, the displayed text cannot be selected or edited. Translating the articles into html and placing them on the course web site circumvented these problems, but students now regarded the articles as "instructor created study materials" and not library resources.

Results of student evaluations of the Jornadas in Developmental Anatomy and Histology (Spring semester) were similar. In focus groups, the main complaints were centered on technical problems plus lack of time to prepare presentations in class. The positive comments emphasized the collaborative aspects of the class exercises, which apparently contributed to a feeling of solidarity among classmates. Students felt that the Jornada sessions made them more accountable for the material and to their classmates, since they had to come to class prepared, and most indicated that they enjoyed the collaborative aspects of class exercises. They indicated that the most effective tool for feedback was the "in-class quiz" and appreciated the variety that the Jornada sessions added to the course. When student point averages at the end of the semester (all test and assignment scores) were compared with those from the previous Spring, averages were higher for the semester of Jornada use (82.7% ± 1.3 vs. 73.8% ± 3.5). Statistical analysis by the t-test gave a P value of 0.068. Since the two semesters utilized the same course materials and were virtually identical in all ways except class exercises using Jornadas, we believe that the computer-based exercises had a positive impact on learning.

Our greatest disappointment with questionnaire results for both courses was that students did not feel that handheld computers would prove useful in future classes for a number of listed activities. After some reflection, however, we realized that technical difficulties encountered at the beginning of our pilot study accounted for much of the students' wariness regarding handhelds. For example, we could hardly expect students to rate handhelds as their desired portals to information on the internet if they failed to transport material from the library located a few blocks from their

classroom. Focus groups and interviews revealed that students desired more portability than offered by the Jornada. "Too heavy and bulky" were common remarks. Students also were disheartened by the tendency of this model to break down. Hinges broke on two units when opened for the first time, two more machines had problems with short backup battery life, and two others had to be reset several times during every classroom period. Additionally, about one third of the machines experienced minor mechanical problems that compounded those due to unanticipated software limitations. Given these difficulties, it is encouraging that all students interviewed expressed a strong desire to see handheld computing become part of the classroom scene, if the above problems could be overcome.

Evaluation of Visor Usage

To evaluate student usage of the Visors outside of class, students kept weekly logs. Although many students lost their logs when battery life expired, the remaining logs were similar to the example in Table 3. Focus groups at the end of the Fall semester revealed that students felt "they did not get a fair test" of Visor use, because they had no way to interface with their personal desktop computer. In this second year of the pilot study, we have alleviated the problem by providing each student with a hotsync cradle. The second most prevalent comment was dissatisfaction with image quality; students especially disliked scrolling to view large graphics. On the positive side, students found it convenient to have portable course materials. Student comments included, "great to store all class notes and info in something so easy to take with you," and "I needed to study, then realized that the information was in my pocket." Most students felt that the Visor was intuitive to use and would be "very nice to have," but indicated that they would need to own the unit to utilize fully its capabilities. We compared point averages at the end of the semester, and found higher scores for the Visor-using group versus the group without Visors (78.4% ± 2.4 vs. 70.7% ± 3.5, P=0.078).

Table 3. Student weekly log of Visor Use in the Developmental Anatomy and Histology of Vertebrates course.

Date	Total time Used	Time used on course	Problems	New applications
8/28	2 hr	30 min	none	iSilo, Graffiti
9/4	30 min	20 min	none	datebook
9/11	1 hr	45 min	none	none
9/18	30 min	30 min	none	none
9/25	2hr	2 hr	none	none
10/2	0	0	none	none
10/9	2 hrs	2 hrs	none	none
10/16	3 hrs	3 hrs	none	none
10/23	5 hr	5 hr	none	none
10/30	3 hr	3 hr	none	none
11/6	3 hr	3 hr	none	tealpaint
11/20	4 hr	4 hr	none	none
11/27	30 min	0	none	puzzle
12/4	1 hr	30 min	none	none

Comparison of Handheld Computers

The Jornada 820 was successfully utilized to achieve most of our pedagogical goals, but was difficult to maintain in good working order. This model has been discontinued and replaced by the Hewlett-Packard Jornada 720, which has a smaller screen, but is more strongly built and reportedly more reliable. We also have examined the Compaq ipaq handheld, one of the Pocket PC family. These PDAs are similar in size to the Palm computers, but have a higher screen resolution, a more capable browser, and the Windows Pocket PC operating system. Although the ipaq has many nice features and can be used for wireless internet access, we find the user interface confusing, and note that it is difficult to exchange information between the ipaq and a Macintosh desktop computer. Additionally, we have encountered a common problem with students who use a desktop PC and expect a Windows-based handheld to have similar capability because the Windows software looks the same. Students in our classes expected Windows CE programs to function as those found on their personal computers and complained vehemently when they did not. It may be an advantage to use a handheld with an unfamiliar operating system that will not raise expectations to an unreasonably high level. A more detailed comparison of handheld computers using Windows CE and Pocket PC systems may be found on the NCSU "Mobile Computing" web site *(http://www2.ncsu.edu/misc/mobile)*.

Whereas the Jornada 820 was subject to an array of mechanical problems, we experienced few such difficulties with the Visors. Students did forget to replace batteries in timely fashion, requiring a hotsync to restore lost material. Several students had to reset their Visors when the system locked up or crashed, but this was not a common occurrence. We plan to try a newer Visor model in the future, probably the Prism (list price $299 US). This model has a rechargeable battery and a newer version of the Palm OS. Its 65,000-color, back-lit screen displays images much better than the Visor Deluxe and also makes text easier to read. With addition of the new wireless module, the Visor Prism will be capable of performing most of the exercises that were successful with the Jornada. The small screen and lack of a keyboard are somewhat limiting, especially if a large amount of text input is required during class. While portable keyboards are available for the Visor, we have not tried them in the classroom.

It is obvious to us that handhelds must be able to interact seamlessly with the internet if their full potential is to be utilized. Students are becoming more dependent on course web sites as sources of materials such as lecture notes, graphics, and study guides. Students would like these web sites to become easily accessed avenues for communication and information exchange with peers and instructors. Our classroom computer of choice must provide a reliable way to access the internet wirelessly. Overall, we prefer to emphasize use of the smaller handheld devices. They are durable, inexpensive, and more portable than the larger mini-laptops. Given the speed at which advances in PDA technology and software are occurring, we feel that Palm-type computers soon will have as much capability as the larger handhelds, and will furnish the "mobile classroom" of the future.

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