Using Mobile Computing to Enhance Field Study

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Abstract

Our research explores the pedagogical, technical, and evaluative issues surrounding the use of a new generation of hand-held, highly portable computers for teaching in the natural sciences. A primary goal is to develop pilot curricula that bring multimedia resources to the outdoor laboratory. Prototypes are being developed for data retrieval and input. It is hypothesized that learners will flourish in situations that provide an opportunity to test skills and theories in the "just-in-time" and "nomadic" field context in which they are used. Can computers enrich the outdoor, field experience by supporting team collaboration for students and teaching staff? This paper sets the background for the mobile computing research project we have initiated, and describes two prototype field applications developed for mobile learning environments.

Keywords—mobile computing, handhelds, situated learning, field study, PDA's, probes

Introduction

As information technologies reshape classrooms and other learning environments, students and educators have become more comfortable with accessing and sharing electronic information. While many educators rely on desktop technologies, textbooks, libraries, and lectures as principal curricular sources, teachers in the natural and biological sciences have often added important outdoor field investigations to their repertoire. Their students usually find this hands-on aspect critical to understanding the subject matter. For example, students of plant biology are frequently attracted to the discipline because of the opportunities it offers to leave the lecture room to explore and learn in field environments.

While field learning cannot be adequately replicated using advanced multimedia technologies, the computer's prowess at information organizing and retrieval can be taken to the field to support learning. Rather than replacing the field experience, new technologies can enhance field work making it pedagogically rewarding. This paper reports on efforts to facilitate the synergy of technology and situated study.

Supporting Technologies

Powerful new hardware and software capable of supporting mobile computing offer new options. Hand-held computers are approximately one-fourth the size of a laptop computer. Some models receive user input from a scaled-down keyboard, while others rely on an electronic pen and incorporate handwriting recognition. For years the misfit younger sibling of the hardware and software community, hand-held computers (sometimes called personal digital assistants) have come of age (Kleinrock, 1997).

Microsoft recently released Windows-CE, an operating system designed for powerful mobile computing applications based on the popular Windows 95. Many major hardware and software vendors are lining up to support this market. For example, RadioMail Wireless Internet Service gives Windows-CE users a constant link and seamless communication between hand-held PC's, desktops and the Internet. The new Apple MessagePad 2000 includes a fast 166 megahertz processor, has ample storage capacity, wireless capabilities and a web browser for searching the Internet. Knowledge Revolution has introduced eProbe, a mobile, computer-based laboratory that connects to a hand-held computer and allows students to collect and visually analyze scientific data.

Literature

Much has been written about the value of teaching science in ways that are authentic and engaging to students as they inquire and collaborate with others. According to Soloway (1996) today's students are not mastering concepts or applying their classroom knowledge, and there is a disconnection between what goes on in school and what goes on outside the classroom. Soloway proposes helping learners to make sense out of their studies by providing tools that "can extend and amplify learners' cognitive processes" (ibid., p.270).

Educational researchers (Resnick, 1987; Soloway, 1996) argue that students learn best when given the opportunity to learn skills and theories in the context in which they are used, then construct their interpretations of a subject and communicate those understandings to others. Mobile computer-mediated learning environments may support this process, helping students find and organize information in context, construct their understandings, and communicate those understandings to others. Mobile computers also support "just-in-time" learning, an adoption by educators of a successful industry technique that involves delivery of parts and finished products at precisely the time in which they are needed (Schorr, 1995). Transferred to education, students may receive context-appropriate information or complete a skill-building task, at the most appropriate teachable moment.

Solomon (1991) suggests helping learners solve ambiguous and complex problems by giving access to data, and by offering opportunities "to collaborate, investigate and create artifacts." A repeated suggestion from these researchers and others (Brown, et al., 1989; Newman, et al., 1989; Resnick, 1987) is that science teaching should engage students in real life problems and promote collaboration.

While there is a wealth of literature describing technology's potential for supporting science education, little has been written from an education or communication perspective specifically about the value of mobile computing. Funded by the National Science Foundation, the "Science Learning in Context" project at the Concord Consortium plans over the next few years "to develop hardware, software, and curriculum material that use portable, networked, hand held computers in student field projects" (Concord, 1997). While no work has been published to date, this project will undoubtedly yield useful information, including valid and reliable methods for measuring effectiveness. In one of a few published efforts, researchers at Auburn University (Foster, 1995) teamed with BellSouth Laboratories to investigate accessing library information using mobile computers. This "Library without a Roof" project showed that it was feasible to gather information from library public access catalogs, databases and the Internet using wireless equipment. The StudySpace Project (Schnase, 1995) at Washington University's School of Medicine seeks to research information retrieval in "nomadic computing environments." Their work looks at the convergence of geographic information systems and hypermedia technologies to help learners gain access "anytime/anyplace." Like the research at Auburn, StudySpace avoids considering the value of mobile computing in learning contexts. Both projects concentrated on technical rather than learning concerns.

Several researchers have examined applications in education of "just-in-time" instructional delivery. Schorr (1995) presents promising results from an experiment "to bridge the technology learning gap between college and the workplace" that relies heavily on a "just-in-time" computer application. Goodyear (1995), with support from the European Community, examines computer-mediated communication with a "just-in-time" perspective. He describes the advantages of distributed access to information made possible by technology. Kribs & Mark (1995) surveyed American trainers in industry, military and higher education, and suggest that awareness is high in the first two sectors but that higher education lags behind in the "just-in-time" trend.

Research Questions

Based on the literature and discussions with university and high school faculty and non-formal educators, the research team has prepared the following questions:

- How can field laboratory experiences for formal and non-formal learners be enhanced by the use of mobile computing technology?
- In what ways, if any, does the mobile computing environment encourage students to contribute to cooperative learning?
- How can mobile computers enhance learning about the scientific investigation process, such as data-gathering and analysis?
- In what ways, if any, will student users take advantage of and benefit from the many tools afforded by the technology?
- What curricula changes, if any, will this new instructional delivery system require of natural sciences educators?
- What features/capabilities should the mobile computing systems provide?
- How do students at various levels of experience use the resources? Are students able to build on skills in this environment?

- Are traditional evaluation methods appropriate for mobile computing instructional delivery systems?

Mobile Computing Project

Our project seeks to develop, refine and evaluate a model of mobile computing in education for formal and non-formal learners. To accomplish this, pilot mobile computing curricula and applications are being developed for undergraduate courses and for informal teaching at our research site, the Cornell Plantations, which is an arboretum, botanical garden, and natural area surrounding the campus. The Plantations offers excellent field environments that are already widely used by faculty for teaching and research. These pilots (two of which are described below) include, for example, applications that allow easy search and retrieval of technical data and enable access to digitized images (i.e. seasonal photos, cross-sections, pathogens, etc.). With faculty collaborators, teaching activities that rely on mobile computing hardware and software are being developed. A goal is to allow more rigorous presentation of concepts and theories as part of the field exercises.

To measure effectiveness, appropriate evaluation protocols for using mobile computers in education—including electronic, on-line tracking systems designed to record student use and progress—are being designed. Finally, the project seeks to distribute tools for working in mobile computing environments, such as guidelines, examples for use, and evaluation methods.

The project is a natural extension of earlier research and development of tools and computing environments prepared by the research team for undergraduate students (Gay, 1995; Gay & Lentini, 1995). The team examined the use of multimedia databases in a networked design environment to learn how students access database resources and shape messages throughout the design process. This work involved studying how engineering design is currently taught, creating database resources and collection tools, and researching how these resources were used. The research team constructed prototype interfaces to help students access large databases. The "Netbook" was used by students for assembling materials from multimedia databases, constructing their own understanding of the material, and communicating that understanding to others. Mobile computers now extend the Netbook tool, permitting data collection and interpretation to occur in nomadic environments.

Pilot Applications

Two pilot applications have been developed in HTML, which enabled use of the material in both a desktop and mobile computing environment. HTML files were loaded locally on the handheld computers and read using browser software. The table below summarizes the audience, content and learning activities for each pilot

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Application	Audience	System Content	Learning Activity
"Cornucopia"	Formal learners (Students enrolled in plant genetics course)	Corn genetics test plot	Access genotype and phenotype database; use electronic field instruments to measure data; record field measurements using computer input form; use desktop visualization tools; immediately compare class data; use desktop applications for group collaboration exercises
"Plantations Pathfinder"	Non-formal learners (casual visitors)	Historic garden (demonstration of plants and their role in modern and ancient history)	Plan tour; Retrieve and record information; use electronic reference guide; Access field notes of other learners

Table 1. Summary of applications developed as pilot projects.

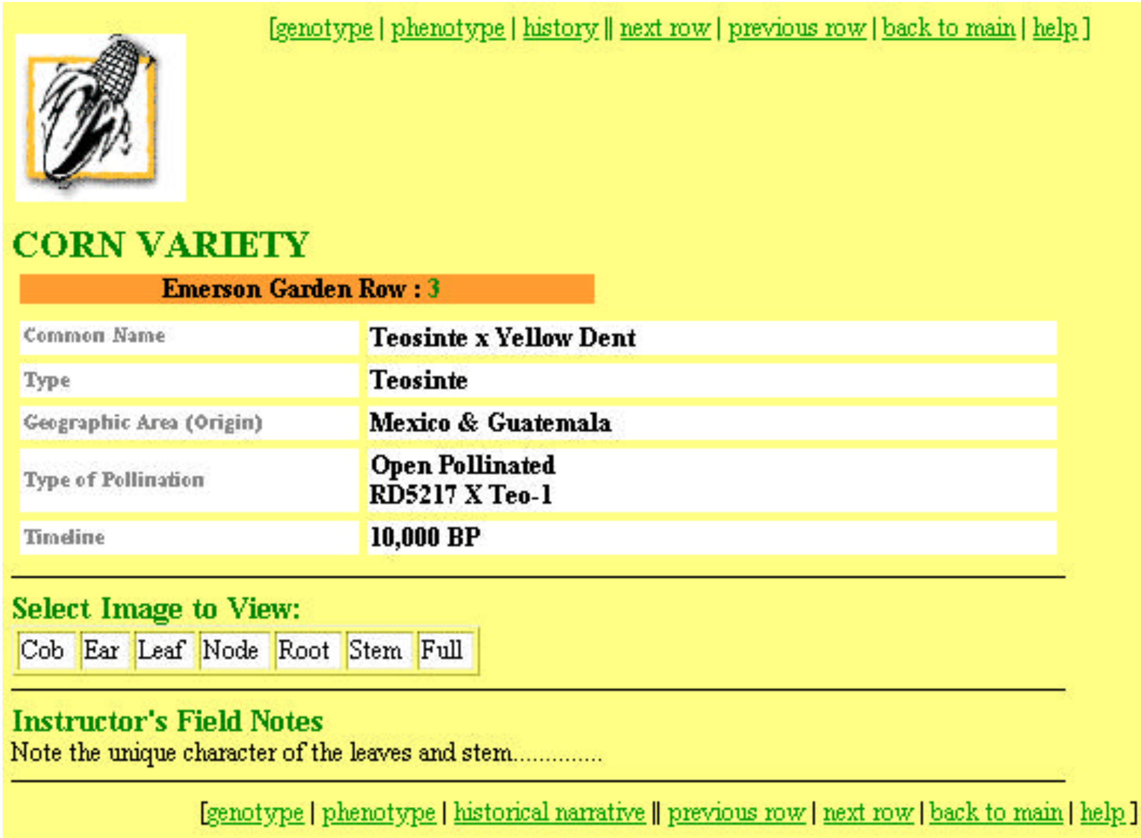

Figure 1. "Cornucopia" database interface.

Cornucopia

The first application, titled "Cornucopia," is designed for use by undergraduate genetics students during laboratory exercises held in a corn test plot sited adjacent to the Cornell University campus. The application provides users with a searchable interface (see Figures 1 and 2) to access corn genotype, phenotype, historical, geographical and other information. Important concepts in plant genetics and evolution are demonstrated by access to digital images of variety traits, genetic models, cross-sections and simulations for selection processes from the field. The structure can be easily modified to accommodate other field learning content, for example, in zoology or biology.

User scenario

One week before the first outdoor field study, the instructor explains the exercise and demonstrates to her genetics class the mobile computing hardware they will be using in lab. To further prepare, students are referred to a web URL that displays the same interface they will be using on the mobile computers. The students meet at the Test Plot and each team is provided a mobile computer, an eProbe data collection instrument, and a memory flash card, which inserts into the portable and holds the lab data entry form and genotype/phenotype database. The teams are responsible for reviewing the database and collecting data—such as plant height, soil pH, temperature, humidity, and growth stage—for ten varieties of corn. They enter their data directly into the mobile computer, which performs rudimentary analysis and displays results. Their flash cards are then given to the instructor who loads data from each of the teams onto a laptop computer for more sophisticated analysis and visualization. After lab, the group files are uploaded to the class web site for further review, and as subject matter for on-line discussions.

Evaluation

Early evaluation efforts have included presentation/feedback sessions with prospective student users, and interviews with faculty and developers. In addition to specific interface suggestions, students and faculty have expressed high levels of interest and enthusiasm for the devices and applications. Frequently they name

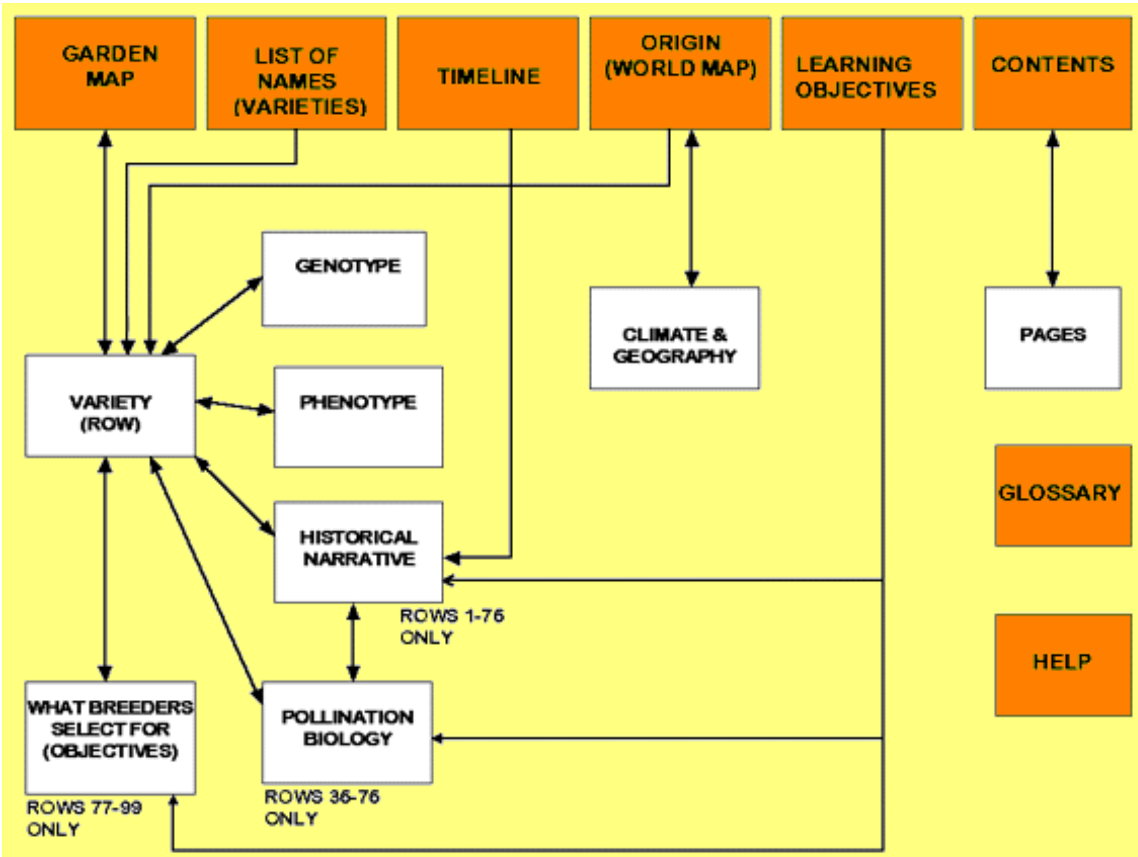

Figure 2. “Cornucopia” content model

other approaches, such as transferring desktop applications they currently use to a mobile environment. Several expressed interest in accessing web sites from the field environment. For example, an extensive database, called MaizeDB, is available on the Web (http://teosinte.agron.missouri.edu/query.html) and respondents suggested relying on this existing resource. Simulations, such as viewing how plants respond to variable growing conditions, were also frequently suggested.

Cornucopia developers offered design and programming suggestions based on their experiences of compiling a system for the handheld. Their suggestions are summarized below.

Screen	•Use limited/small graphics •Avoid html-based tables (currently) •Avoid color •Maximize contrast between text and background for visibility •Minimize repeated menu items on each screen (i.e. create a navigator or pull down menus rather than take up valuable screen real estate) •Use large/simple fonts
Portability	•Create context-free information (modular) •Minimize the amount of back and forth shifting that the user needs to do between screens by making each screen self contained •Create a docking environment with a desktop application
Content Planning	•Keep content specific to the field environment •Avoid making the mobile computer into a mini-desktop •Use it as a dedicated tool to optimize its strengths and minimize its limitations •Focus on tutorials, data collection, or diagnostics
Other	•Most mobile systems are not able to use HTML tables or frames •There is a lack of integration between forms and HTML use of other development languages (i.e. Visual Basic or Visual C++ or other for creating a more natural feel to the application)

Table 2. Design and planning suggestions for mobile computing applications.

Plantations Pathfinder

The second pilot application, called Plantations Pathfinder, is designed to supply information and provide a collaboration space for visitors (informal learners) as they move about the gardens. At first, the program serves as an electronic tour guide, or interactive docent, enabling visitors to customize their visits and access information about plant uses, history, economics, and more (see Figures 3 and 4).

The Plantations is a "living museum" and as such is in constant change. An electronic guide can be kept updated more readily than printed materials. It can keep a record of the interests of the visitor and collect information for them to take home, such as by printing their "journal" upon returning to the visitor center. As a collaboration tool, the system enables users to input information which can then be uploaded to an electronic discussion forum. Much like the comments books provided at museums and other sites, visitors can view reactions and advice of others.

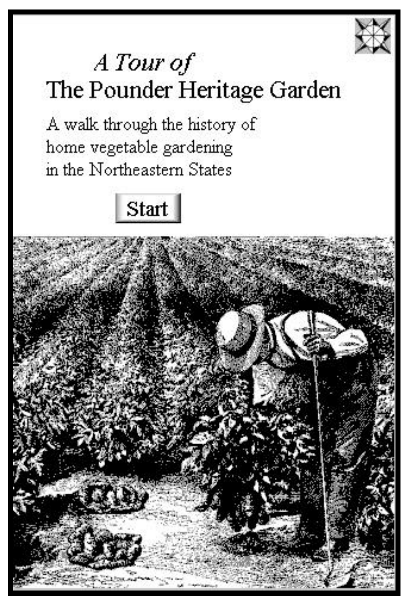

Figure 3. **Pounder Heritage Garden opening interface.**

Figure 4. Pounder Heritage Garden introductory page.

User Scenario

Prior to visiting the Plantations, visitors log on from the desktop to the Plantations Web site where they can access the actual interactive tour they will be using on a handheld computer. At the site, users receive more information about a particular garden, including searching a multimedia database highlighting the thousands of plant varieties cared for by the Plantations staff. Once at the Plantations, visitors may want to learn more about historic varieties of squash. They borrow the "Pathfinder" hand-held personal computer from the Visitor Center, then tours the squash garden, consulting the application, adding entries to a personal journal, and making notes that can be uploaded later. They also search and view the comments of previous visitors.

Evaluation

Feedback to the Pathfinder have included presentation/feedback sessions with prospective, informal Plantations visitors and students, and a printed survey of volunteer educators at the Plantations who work directly with the targeted user audience. Like reaction to “Cornucopia,” many expressed strong enthusiasm for the prototype, although many said that it would not be suitable for every visitor. One visitor noted a positive use of a similar system at an art museum. They suggest that the application can provide more in-depth information than the labeling systems, and more timely information than printed resources. They saw value in handheld computer presentation of plant locations, images, taxonomies, historical and care information, and sources for purchasing plants. Other visitors were less enthusiastic, saying “It could spoil the joys of wandering in a garden,” or “I wouldn’t want it to get in the way of us and the garden.”

Conclusion

Through evaluation of two pilot applications, the research team has learned much about the appropriate design of mobile computing to support field experiences. For example, while the field assistant should leverage the appropriate strengths of the field environment (i.e., the ability to gather and analyze data right in the field), designers should not neglect including traditional resources that can be accessed from the field. Data from Maize DB for genetics students or Gray’s Anatomy for medical students, for example can be liberating when extended to the field setting.

Planning for these systems needs to be heavily user-based. Rather than seeking to develop monolithic tools presumed to work for all needs (like a textbook), creators of the mobile future need to design powerful, easy-to-use design tools that allow experts (such as teachers or museum docents) to shape the technology for their unique needs. Design templates and mechanisms for incorporating other databases will be important areas of future research in this project. A priority now is to consider what makes field study attractive and valuable to begin with, independent of new technologies, which we can learn from educators who do a considerable amount of work in field environments.

Mobile computers have made valuable contributions to several industries and the list of new applications continues to grow. Explorations by researchers of the contributions these devices can make within the education community can set educators off on the right path.

Acknowledgements

The authors gratefully acknowledge the work and assistance of our colleagues and students: Gale Halpern, Daniel Allen, Richard Marisa, Lindsay Hamilton, Gisclerc Morisset, Jon Griffin, Donald Rakow, Margaret Smith, Christine Doell, Noni Korf, Carolyn Yaeger, Dorothy Reddington, John Morse, Mary Hirshfeld and Krissy Faust.

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