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CILT2000: Ubiquitous Computing – Spanning the Digital Divide

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This paper discusses the role of ubiquitous and handheld computers in education. CILT contributions in this area are summarized, the Ubiquitous Computing sessions at the CILT2000 Conference are described, and future directions are highlighted. It is posited that handheld computers have the potential to reduce the digital divide, while also providing for a wide array of learning activities that can benefit all students.

KEY WORDS: technology; ubiquitous computing; handheld computing; equity.

THE CASE FOR HANDHELD COMPUTERS

There is great concern that the increased use of computers in education will only drive another wedge between rich and poor, known as the "digital divide." Poorer schools appear to be at least 2 years behind more privileged ones in most measures of educational technology implementation and use (see http://nces.ed.gov/quicktables/).

While schools struggle with this issue, the ongoing revolution in information technologies continues: computers will soon be very inexpensive and ubiquitous. Most people will own several, including toys, TVs, phones, pagers, handhelds, as well as general-purpose computers, and all will communicate with a ubiquitous network.

This means that the desktop computer and its close cousin, the full-featured portable, will represent just one end of a spectrum of intelligent personal assistants. Full-featured computers already have far more power than most educational applications need. Eventually, simpler computers with fewer options and compact operating systems costing a fraction of desktop computers will be marketed to meet the needs of learners.

When the Center for Innovative Learning Technologies (CILT) was being formed in the fall of 1997, it determined that handheld computers represented an area in which a breakthrough in education could be expected in a few years through research and development. As a consequence, CILT created a Ubiquitous Computing "theme team" to focus on stimulating research, applications, and educational implementations of inexpensive, portable computers. CILT viewed this as an important equity issue because these computers have the potential to provide much of the educational benefit of more expensive computers in an inexpensive, portable format. However, handheld computers should be seen as not only an inexpensive way to increase equitable access to the educational benefits of desktop computers—by taking advantage of their portability and convenience we expect to find ways to provide a better education for our students. This technology will soon give students full-time access to computation and wireless connectivity, while expanding educational computing to take place at home and in the field.

CILT CONTRIBUTIONS

CILT has had an active role in bringing handheld computers to the forefront of educational technologies. Prior to beginning its work, there was a deadlock. There was little research to show the value of handhelds, and there were few educational

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applications. As a result, educators quite rationally ignored them, and vendors, lacking an installed base, saw no reason to develop educational software. Through modest investments, CILT has been a significant force in breaking the deadlock.

Over the last 4 years CILT Ubiquitous Computing activities have included

- A design session with IDEO that resulted in a description of an ideal educational handheld. This paper has influenced the thinking of many people in the field. It can be found at http://www.cilt.org/images/DataGotchi.pdf
- The development of "SmartProbes" by designers at the Concord Consortium. SmartProbes are data collection and analysis tools consisting of low-power sensors with microprocessors and computer software that provide the user with easy, real-time data acquisition and display. More information on SmartProbes can be found at http://www.concord.org/library/1998spring/smarterprobes.html
- The organization of an educational software competition for handheld computers running the Palm operating system. See http://kn.cilt.org/palm99/
- Valuable research on the use of handheld computers and probes in science classes in close collaboration with the CILT Synergy theme team.

This combination of technology development, software development stimulation, and pilot research appears to have generated interest in educational applications of handheld computers.

THE CILT2000 CONFERENCE

The Ubiquitous Computing sessions at the CILT2000 Conference brought together a diverse group of researchers and developers, each with an interest in applications of low-cost ubiquitous computing to education. Presentations were given on the following topics:

Using low-cost handheld computers and probes in science education
http://www.imagiworks.com/
http://www.pasco.com/
http://mit.concord.org/
http://hi-ce.eecs.umich.edu/teacherworkroom/index.html

Using graphing calculators and wireless networks for meaningful collaborative activities and "participatory simulations"
http://www.ccl.sesp.northwestern.edu/ps/overview.html

Creating simulations on handheld computers
http://geney.juxta.com/

Using wireless networking on K-12 and college campuses
http://www.nomad.cornell.edu/

Using handheld technologies at science and technology centers
http://www.exploratorium.edu/guidebook/

Creating novel manipulative environments
http://llk.media.mit.edu/projects/summaries/toys.shtml

After these presentations, the group brainstormed about future directions, selected the highest priority areas, and developed four of these. One group considered *wireless affordances* as an area for potential breakthroughs in education. This group asked: What new activities can students participate in, once they have true collaborative writing and peer editing capabilities, the ability to share simulations and aggregate data, all while using a truly personal and portable device? And, as issues of assessment and accountability remain important, how can we leverage wireless devices for new, authentic forms of inquiry?

Another group investigated *device design.* With the exception of Apple's discontinued eMate, powerful, portable, handheld personal computers have been designed to meet the needs of professional and business users. The needs of these users may be significantly different than the needs of younger learners. This applies to the design of hardware, operating systems, and applications. This group subsequently received a CILT seed grant to investigate a broad range of design issues.

The lack of *learning applications* was the focus of another group at the conference. Until there is a critical mass of applications designed specifically for learners, it is difficult for teachers to justify the use of handheld technologies in the classroom. Since the conference, some headway has been made in this area (see, for instance, the University of Michigan's efforts at http://www.handheld.hice-dev.org/, and listings of educational software such as http://www.palmcentral.com/3com/education.shtml and http://www.concord.org/probesight/curriculum/template_section.htm). However, more research and development is still needed to more thoroughly explore the educational potential of this medium.

The *bridging learning communities* group considered the implications of ubiquitous access to computers for traditionally underserved communities and the role of partnerships of formal and informal learning institutions in meeting the needs of these communities. This group received a CILT seed grant to begin the process of formulating a research agenda in this area and seeking funding to pursue this research.

CURRENT ACTIVITIES

Innovations in handhelds and probes have continued from the strong base of the initial CILT work. At the Concord Consortium, staff members have developed heat conductivity probes and visualizations, wireless networking of handhelds and sensors, new interfaces, and platform independent software. For instance, the Concord Consortium has developed a new voltage probe that promises to greatly reduce the price of probes. While the interface itself measures only voltage, its extraordinary sensitivity permits it to be used with very simple and inexpensive transducers that students can attach to its inputs to create new probes. For instance, the stretching of a wire can be used to measure force, the junction of two different wires measures temperature, and inexpensive LEDs can measure light level.

Equipping a year-long course for probe-based activities might require ten or more sensors each costing between $35 and $100 or more if they are purchased already assembled and tested. The resulting costs are so much more than the costs of handhelds that schools will be most reluctant to use probes with inexpensive computers. With this new approach, students make probes from parts costing very little, resulting in a far more reasonable system cost. This approach not only reduces costs, but also allows students to create their own probes, seeing how voltage inputs can be used with transducers to measure almost anything. The research centers around what students actually learn in this context and whether the teacher professional development demands of offering a do-it-yourself approach are reasonable (for more information, see http://concord.org and search for the TEEMSS project).

The CILT smart interface was the key technology in a National Science Foundation grant to the Concord Consortium. The Technology Enhanced Middle School Science project (TEEMSS) is a curriculum study that is creating two physical science units, based on the smart interface, which explore the feasibility of kit-based probes in the classroom and the concomitant teacher professional development issues. The curriculum topics, *energy and force and motion*, are challenging for many teachers and require at least five sensors: force, motion, electrical power, temperature, and light. To keep costs down, a new motion detector is being developed based on recording the rotation of a wheel.

All software development for TEEMSS is being done in Waba, an open source variant of Java designed for wireless handhelds. One of the most valuable characteristics of Waba is that it runs on all the available handhelds as well as Macintosh and Microsoft OS computers. Concord staff are using the same programs on Palm, iPaq, and Macintosh computers and have also used the wireless capacity of Waba with the iPaq to transmit data wirelessly from sensors to the computer and to share data between computers.

Another result coming out of CILT efforts is the Palm Education Pioneers program (PEP), a program funded by Palm and run by SRI International to equip over 175 classrooms with full classroom sets of Palm computers. This program promises to make a significant contribution to our understanding of handheld technologies for education (see http://palmgrants.sri.com). In addition to this close collaboration with Palm, CILT has also maintained regular contacts with Intel, Casio, Texas Instruments, Hewlett Packard, Handspring, and others.

FUTURE DIRECTIONS

The Ubiquitous Computing theme has had a major impact on education through a mixed strategy of technological innovation, advocacy, and classroom demonstrations. Its efforts have undoubtedly led to a greater appreciation for the role of handhelds in education. Because of their low cost and unique portability, this has important equity implications. Once there are more educational applications available and current research begins to provide a solid backing for the educational value of these applications, every child should have a handheld. Then these computers will become ubiquitous educational appliances.

We expect to see a new trend in educational technology access over the next decade. The current technology gap will dwindle into insignificance within a few years as prices drop dramatically for personal, handheld computing technologies. This is because information technologies are relatively low-cost and dropping. Unlike jets, reactors, and rockets, computer and network technologies are "democratic technologies." Like TVs, VCRs, calculators, and radios, information technologies will soon be ubiquitous. Except for a few rare cases, we expect the situation throughout the world to be essentially similar. In most parts of the world, the huge digital divides that exist today will close as access becomes ubiquitous. Many countries already exceed the access to technology in the United States and even developing countries see the importance of computer and networking technologies and are making them widely available.

In light of these trends, CILT has decided to shift the emphasis of the Ubiquitous Computing theme from access to educational uses of the technology. We find that the most interesting applications of ubiquitous technologies involve supporting student inquiry. As a result, we have broadened the theme to "Supporting Inquiry Using Ubiquitous Technologies." The new research includes a focus on *tools* that support inquiry *including ubiquitous computing tools* as well as tools that are currently being developed by CILT institutions (e.g., hypermodel applications at the Concord Consortium, http://www.concord.org/library/2001spring/cover.html, and Web-based Inquiry Science Environment [WISE] at UC Berkeley, http://wise.berkeley.edu/WISE/welcome.php). Broadening the theme to "Supporting Inquiry" also allows investigation of teacher interpretations of inquiry as well as student outcomes in inquiry-based environments. Our research is intended to anticipate ubiquitous learner access to small, portable computers that are frequently linked to each other and the Internet through wireless technologies.

One research project underway investigates how teachers support inquiry in their classrooms. This project seeks to understand teachers' definitions and enactments of inquiry in their classrooms. The following research questions guide the study:

- How do teachers describe inquiry?
  - What terms do they use?
  - How do they describe what students would be doing in support of inquiry?
  - How do teachers describe/relate to each of these activities: problem formulation, data collection, analysis, argument construction, and assessment?
- How do teachers currently support inquiry in their classrooms?
  - What inquiry-related activities do they use with their students?
  - What technologies/tools do they use (WISE, Palms, probes, hypermodels)?
  - What supporting strategies do they use?
- How can we prepare teachers to integrate inquiry into their classrooms?
  - How can combinations of netcourses, workshops, and mentoring be effective?
  - How can we address pedagogical knowledge (teaching strategies), conceptual knowledge (what inquiry is), and epistemological knowledge (nature of science)?

A study of these questions is currently underway at Foothill Middle School in Walnut Creek, California. Two teachers who are participants in the study are using a range of tools to support inquiry including WISE, handhelds, and probes.

One promising set of tools to support inquiry is being developed at the Concord Consortium. These *hypermodels* consist of a control program called Pedagogica and software tool environments like probeware, NetLogo, and models. Pedagogica provides scriptable interactions with students that provide scaffolding and embedded assessment. The scripts provide detailed control of the options presented, the initial conditions, questions asked, and sequences of events. Pedagogica can generate student assessment data by noting what choices students make, how long they take, and what help they require as they solve challenges. The scripts can be delivered and the assessment data returned over the Internet, making remote research feasible. Hypermodels are nearing completion for genetics, molecular dynamics, and probeware. Once these are complete, a number of studies are planned that use the assessment capability of Pedagogica.

A second tool designed to support inquiry, WISE, will also be the focus of future CILT work in this theme. A new project within WISE will be developed to support student inquiry within the domain of geology. Students will be guided through an investigation of the rock cycle and concepts including conservation of mass/energy. This activity will be designed and developed by Yael Kali and Michele Spitulnik.

As schools begin to see that low-cost, handheld computers can help bridge the digital divide of access, educators, and policymakers will ask for data on proven approaches that can be used to help bridge the digital divide of technology use. The CILT activities described here will provide some of the research results that are needed.