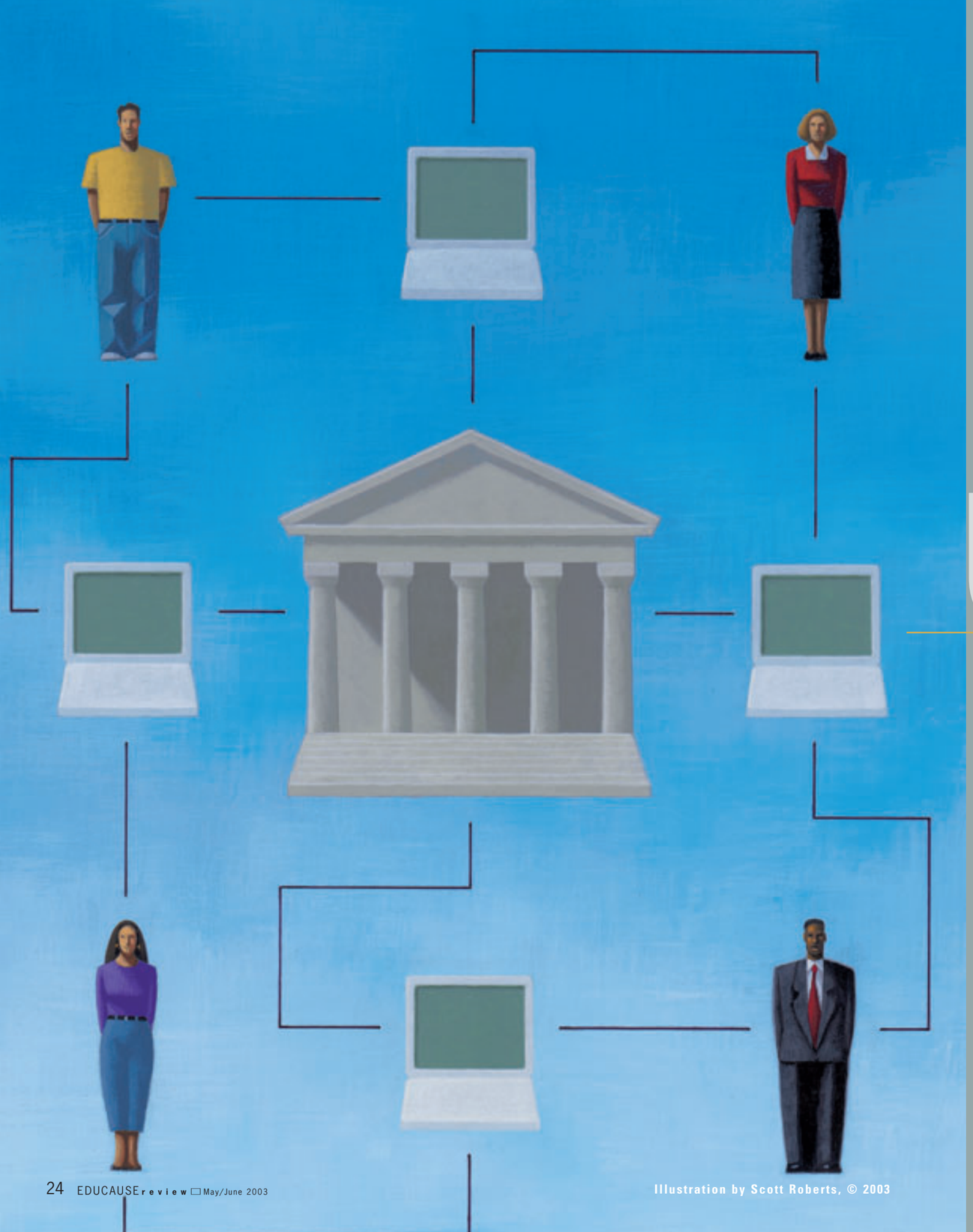


Illustration by Scott Roberts, © 2003

The Status OF Ubiquitous Computing

By David G. Brown and Karen R. Petitto

The ubiquitous computing movement is suffering an identity crisis as a result of its own success. At its zenith, the movement was led by campuses where all students had laptop computers, all similarly configured. Then, as now, the objective of the movement was that teaching should proceed on the assumption that every student and faculty member has appropriate access to the Internet. Today there are over one hundred laptop campuses. Most are in Canada and the United States. Within larger universities are another fifty-plus subgroups, especially colleges of business and engineering, that require commonly configured laptops of students and faculty in the programs. Beyond these universal laptop programs, we estimate that at least half of all colleges and universities in the United States are "practicing ubiquity"—that is, teaching proceeds on the assumption that every student and faculty member has appropriate access to the Internet. Ironically, the tight definition of *ubiquitous computing* no longer prevails because the concept itself has become ubiquitous.

David G. Brown is Vice President and Dean of the International Center for Computer-Enhanced Learning at Wake Forest University. Karen R. Petitto is Assistant Professor of Educational Technology and Instructional Technology Specialist at West Virginia Wesleyan College.

The Rationale for Ubiquitous Computing

Faculty in most institutions throughout the developed world have decided that it is intolerable to "dumb down" teaching and learning to accommodate those few students who shun Internet use. Just as for decades faculty have assumed that students will have access to textbooks, library resources, and laboratory facilities, so the new assumption is that all students will have reasonable and regular access to the Internet. Just as for decades developed societies have presumed that almost everyone can be reached by phone, so today a majority of academic communities are presuming that students and faculty communicate via e-mail and Web pages.

Investments in ubiquitous computing are beginning to be justified by research on learning outcomes. Shouping Hu and George D. Kuh noted, from an analysis of responses to the fourth edition of the *College Student Experience Questionnaire* (*CSEQ*) completed by 18,844 students at seventy-one U.S. colleges and universities, that students at campuses with greater availability of computers reported more student-faculty contact, greater cooperation among students, and more active learning.[1] Ross Griffith, in before (ubiquitous computing) and after analysis of *CSEQ* responses by students at Wake Forest University, found significantly more co-curricular participation and computer usage, as well as greater development of interpersonal communication skills, of skills related to the integration of knowledge, of specific skills in the disciplines, and of the skills needed to locate and evaluate information.[2] Ubiquity is making a difference!

The biggest advance seems to be in communication and community building. Students are more active members of more intellectual and co-curricular subcommunities. Communication between professors and students, and among students, is more timely, more frequent, and more substantive. The bonds among colleague learners and professors linger longer. E-mail, which Hu and Kuh found to be the electronic method most frequently used to support teaching, is a very powerful benefit for professors and students in these ubiquitous environments where everyone is part of the system.

The Hierarchy of Ubiquity

The major question about ubiquitous computing has shifted from "whether ubiquity?" to "how ubiquity?" Is it enough simply to teach on the assumption of universal access and to let students use their initiative to get to some computer, with some capacity, with some software configuration, with some reliability of operating? How important is it, at the other extreme, that all students have powerful handheld computers with standard software? Both circumstances reflect a ubiquity of computers, and yet they differ greatly in their cost. What is the best balance of cost and benefit?

Hierarchy of Ubiquity

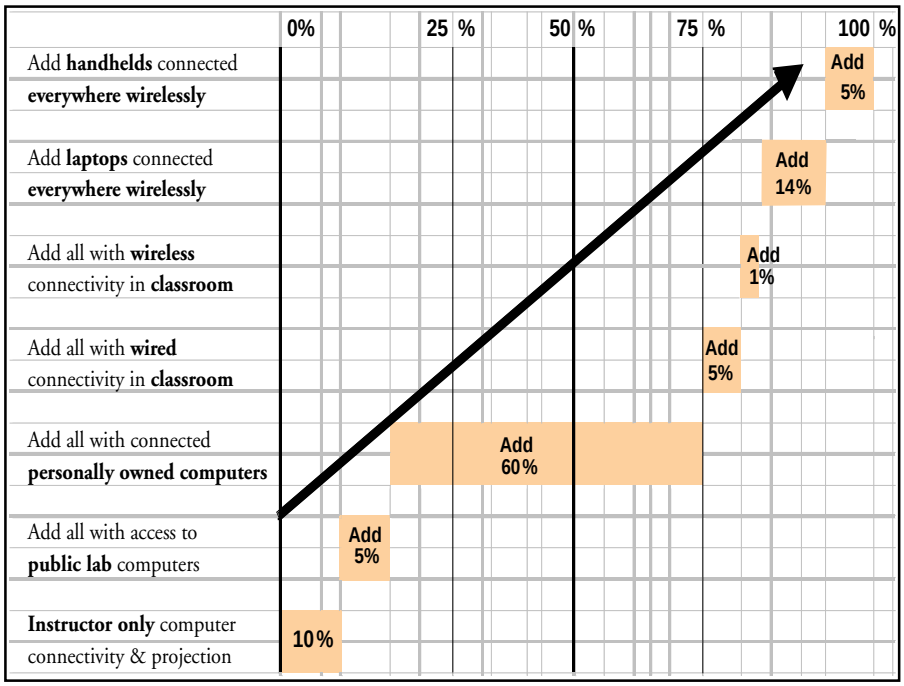
- All "Own" Identical Laptops + 2-Year Refresh
- All "Own" Identical Laptops
- All "Own" Threshold Laptops
- All "Own" Identical Desktop Computers
- All "Own" Threshold Computers
- All "Own" Network Computers
- All Have Access to Threshold Computers
- All Have Access to Public Computer Labs
- Teach with Explicit Assumption of Access

From our experience in workshops and consultancies involving nearly three hundred campuses,[3] we risk rough estimates of the value added by moving up the hierarchy of ubiquity (see table 1). We start with the basic assumption of a campus that has a sprinkling of computers among faculty offices, the library, and computer labs—perhaps a computer for every six members of the community. Then we suggest what portion of the gain achievable from the highest level of computerization is likely to be added by successive increments of equipment cost.

At the second level—providing all professors with computers and the capacity to project computer images, both from local hard drives and the Internet—a campus can move 10 percent toward the full benefits of ubiquity. Adding generously equipped computer labs throughout campus moves the institution another 5 percent, for a total of 15 percent, toward full benefits.

The big benefit comes not with spartan ubiquity but when all students also own (or personally control) a computer—either a laptop or a desktop computer. With assurance of universal access, professors are much more willing to give

Table 1. Value Added along the Hierarchy of Ubiquity



[100% of the value of ubiquity is achieved when everyone has access everywhere.]

Internet-dependent assignments. With the convenience and familiarity of a personally configured computer, students naturally use it as a basic life tool. With the high likelihood that friends and classmates, as well as professors, will access their e-mailbox daily, the pace and the reliability of all communication increase manyfold. Our estimate is that 60 percent of the total gain from ubiquity comes from this single increment.

Most of the computer usage, even on the most fully wired and equipped campuses, occurs between class times. Very few professors regularly insist that all students be connected to the Internet during all class periods. With the exception of instruction on how to use the computer, it is usually best to use face-to-face time for discussion, for visiting lecturers, and for other activities that are less effective when pursued virtually. The power of the computer is to extend time on task and to perform, out of class time, those learning activities that are best supported virtually.

At this point, although there is some difference of opinion among campuses, classroom-only wireless yields very, very small gains (1 percent). Only on campuses where wired access to the Internet is severely limited is there a justification for going wireless for the sake of learning. Clearly, there are increasing numbers of "boutique" uses of wireless computers, but the large increments of gain from wireless must wait until the technology is faster or more reliable. Here the new standard of 802.11a offers substantial promise.

The upgrading of universal computers from desktop to laptop adds, by our estimate, another 14 percent of value. Faculty laptops are often carried home, where faculty members' children often teach new computer skills to their parents and where faculty members are more likely to answer an evening e-mail from a student. With laptops, students are more likely to use their computers when studying in groups or when visiting a faculty office. And the computer-dependent networks and skills to which students become accustomed while on campus are available when students use their laptops while on break at home or while studying abroad.

Finally, there are uncertain gains from "going handheld." To date, large increases in value have been seen in very limited applications, such as medical students using handhelds to access databases when at the bedside of patients. Given the current problems of input and screen size, and the convenience of laptops, handheld computers are unlikely to become broadly used within higher education. With new technological developments, solutions to these problems may be found, but they are probably a number of years out.

Although not reflected in table 1, there are also gains to be achieved with standardization, of both hardware and software. At a given cost, standardized systems are both more reliable (because building in redundancy and training system-maintainers is easier when the number of contingencies is more limited) and more usable (because users of similar configurations are more likely to be able to answer another user's questions).

Lessons Learned by the Pioneers

In 1997, roughly one hundred institutions involved in some form of ubiquitous computing were invited to participate in the First Annual Conference on Ubiquitous Computing. Some campuses, such as Dartmouth and Drew and the U.S. military academies, had been engaged with ubiquitous computing since the early 1980s. From this group came most of the thirteen institutions that later agreed to write up their experiences, resulting in the book *Ubiquitous Computing: The Universal Use of Computers on College Campuses.* Leaders from each institution explain the learning concepts that shaped their decisions, the politics of consensus, and the keys to successful implementation. Together, the thirteen essayists contributed to a listing of lessons learned and suggestions to other institutions that are implementing the ubiquitous computing strategy.[4] This listing is reproduced in the following sections.

Lessons on Planning for Ubiquitous Computing

1. Don't lose sight of the ultimate goal: measurable improvement of education outcomes. Keep the focus on

pedagogy, not technology. Remember that students are the center of the program: everyone else is important, but the program serves the students directly. Stay focused on the goal of enhanced student learning.
2. Clearly defined, defensible program objectives are essential.
3. Develop a comprehensive plan first and quickly match it with a multiyear financial plan. Establish a clear financial plan and budget and a mechanism for revising the budget annually. Include adequate startup and operating funds.
4. Demand for technology will increase much faster than anticipated.
5. Most sunk costs (for example, old computers) can be ignored.
6. Getting laptops to students is only 10% of the challenge; decisions about, and implementation of, policies, training, support, networking, exposure, and motivation remain ahead.
7. Recognize that user-friendly technology in the hands of dedicated faculty is the most powerful change instrument that any academic administrator has ever had.
8. Top executive support is essential.
9. The impact of computing on teaching and learning is difficult to assess objectively.
10. Disciplines use the computer in different ways, so a broad spectrum of faculty must participate in system design decisions.

Lessons Learned by:

Acadia University (Canada)
Clayton College and State University
Dartmouth College
Drew University
Drexel University
École des Hautes Etudes Commercia (HEC) (Canada)
University of Hong Kong
University of Minnesota, Crookston
Rensselaer Polytechnic Institute (RPI)
Seton Hall University
SUNY-Morrisville
University of Strathclyde (Scotland)
Wake Forest University

Keep the focus on pedagogy, not technology. Remember that students are the center of the program.

Lessons on Technology Itself

1. Reliability is crucial, especially in a robust network and trained help desk.
2. Standardize on hardware, software, and ISP at least at first. Standardization pays rewards well beyond those anticipated.
3. Pay attention to the logistics of distributing equipment: it's harder than you think. Laptop distribution is a major production: define each step and automate everything possible.
4. Don't accept the first bid from a vendor: the market is competitive, and vendors will improve their bids. Develop strategic partnerships rather than just buying from vendors. Choose a partner for the long haul.
5. Models and prices change fast: don't buy too early in the year and then be forced to deliver a discontinued model to your students, while they read ads in the newspaper for new machines at fire-sale prices.
6. Sign procurement contracts with major vendors specifying their responsibilities for delivery and for equipment that fails initially or repeatedly.
7. Technology will sometimes fail.
8. Have a structure for student repairs.
9. You can never have enough bandwidth to the Internet or network disk space.
10. One of the biggest financial challenges is what to do with laptops used for a semester or two and returned when a student withdraws or is dismissed.
11. The help desk must be close to classrooms.
12. Wireless is worth it: don't hesitate too long, and be complete with your wireless coverage.

Lessons on Implementation and Management of Ubiquitous Computing

1. Professional project management is essential, especially during startup.
2. Be prepared to outsource challenges; consulting help is essential.
3. Use commercial course management software.
4. Spread the gains from, and ownership of, innovation throughout all units. Identify and incorporate existing assets before creating new ones.
5. Balance central services and local control.
6. Provide academic units staff of their own and plenty of equipment without hassle.
7. Put in place an ongoing faculty and student-led oversight mechanism to monitor and to adjust the program. Place some funds under faculty control. Apply academic review structures to the program. Don't let administrators have control of faculty development.
8. Understand the role of standards in the program, and obtain agreement on them from faculty and administration.
9. Ultimate responsibility should be given to a senior administrator with the authority to set directions and settle disputes.
10. Never underestimate the power of teamwork.

11. Involve parents as early as possible.
12. Hardware and software decisions are separable.
13. Communicate, communicate, communicate frequently with all stakeholders.
14. Manage expectations; they invariably outrun the capacity to deliver. Address faculty and student concerns truthfully, adequately, and quickly in order to quell rumors. Keep your admissions office informed. Regularly reconcile program descriptions in university publications with those on the Web.
15. High percentages of faculty will use the computer if their initial introduction involves only email, URL addresses, and course materials posted by a course management system.

Lessons on Adoption of Computer-Enhanced Learning

1. Plan a Pilot Year to purge bugs when stakeholders will still tolerate imperfections.
2. Provide students and faculty just-in-time training that centers on the task-at-hand; general classes don't work well.
3. In a standardized environment, students learn basic computer skills quickly, without degree-credit incentives.
4. Standardization speeds faculty adoption and eases the pressure on support staff.
5. First encourage easily learned and administered uses of the computer by a high percentage of faculty; leave the more difficult and expensive uses of the computer until later.
6. Early academic involvement and leadership is critical to success.
7. Make use of student expertise to support peers and faculty.
8. Student access to computing can vary even in a highly standardized environment. Students aren't all computer wizards. Some can be archly conservative.
9. Coordinate the technology program with existing programs for faculty development and training.
10. Continue, long after program launch, to provide faculty training.
11. Recognize that it's quite possible to launch an online course for less than $30,000.
12. Avoid minimum expectations about the amount and character of technology to be used in individual courses.
13. Find opportunities for faculty to showcase the results of their work.
14. Develop intellectual-property policy that benefits both individuals and university.

Lessons on Results

1. Contact among students and between students and faculty becomes continuous.
2. Students teach faculty, and friends serve as an informal help desk.
3. Co-curricular activities thrive due to increased communication. Student groups are larger and more active.
4. Team assignments are more frequent and more easily completed.
5. Computers are a boon to student recruitment, retention, and self-confidence.
6. Computer availability throughout the student body attracts new faculty.
7. The greatest benefits are seen in what happens between classes, not during class.
8. If students are provided a standard platform with a standard software load, faculty will voluntarily and rather quickly migrate toward the same standard.
9. Student presentations are more substantive and polished.
10. Student preservation of electronic materials is greatly facilitated by rewritable CDs and a program for creating portfolios.

Program Changes

Typical of today's laptop programs are those at Wake Forest University and West Virginia Wesleyan College (see table 2). Like many other programs, these two have evolved around three issues: (1) vendor, (2) institutional model, and (3) funding.

Vendor

Many of the pioneer campuses entered their ubiquitous programs with vendor partners. Vendor partners were able to work with the colleges and universities to determine a computer configuration that was right for the institutional application. Vendor commitments were also important in the computer-acquisition process. Because the academic calendar includes little flexibility, it was very important for computers to arrive as scheduled. Today, many ubiquitous campuses report that the vendor plays a less important role in their program. Whereas in 1996 and 1997,

Table 2. Laptop Programs at Wake Forest and West Virginia Wesleyan

Wake Forest in 2003	West Virginia Wesleyan in 2003
• Laptops & printers for all students & faculty • New every 2 years • Own @ graduation • Standard software • 31,000 outlets & wireless	• Laptops for all students & faculty • New every 3 years • Standard software • Wired & wireless campus
Standard Hardware includes— IBM A30, Pentium III, 1.13GHz Processor, 30GB Hard Drive, 384MB Ram, 15" ActMatrix Screen, CD-RW/DVD, Floppy, 56k Modem, 16MB Video Ram, 10/100 Ethernet, USB & Serial & Parallel & Infrared Ports	Standard Hardware includes— Intel Celeron 700Mhz, 128MB Ram, 10GB Hard Drive, 24x CD-ROM, Trident CyberBlade Ali (AGP 2x) Video Card, Ali Audio Drive (Sound-Blaster Compatible Sound Card), Lucent Technology 56K WinModem, Xircom 10/100 Ethernet Card
Standard Software includes— MS Office, Dreamweaver, SPSS, Maple, Acrobat, Photoshop, Shockwave, Flash, Net Meeting, Real Produce & Player, Media Player, Windows XP Moviemaker, Apple QuickTime, Netscape & Explorer, Netscape Calendar & Communicator, Windows XP Professional	Standard Software includes— Microsoft Windows Millennium, Microsoft Office XP Professional, Microsoft Messenger, Winamp, SPSS, Norton Anti-Virus, Windows Media Player, IBM Wireless LAN

ubiquitous campuses were just beginning to develop their programs, today campuses have years of experience on which to draw for implementing, assessing, and fine-tuning their programs. Vendor decisions now are based on machine specification and durability more than any other factor.

Institutional Model

The institutional model of ubiquity continues to change. The college/university campus is a dynamic environment, and ubiquitous programs that are flourishing have learned that in order to continue to provide a program that fits the campus, they must quickly respond to the way faculty and students utilize the technology. Students can now bring laptops to their student employment positions, allowing them to participate in more engaging work. Students can take mobile computers with them to internship placements. Computer labs may be reduced or eliminated. Mobile computers allow classes to meet in a variety of locations.

Many of the issues surrounding the institutional model were presented above in "The Hierarchy of Ubiquity" section. Other considerations include the following:

1. Will all students have the same model of computer?
2. Will students keep the same computer for all four years, or will there be a refresh period?
3. Will faculty have computers comparable to the students' computers?
4. What campus resources (e.g., labs) can be reallocated because of the mobile computer program?

Laptop campuses have learned a lot about the maintenance and upkeep of the computers. A single computer model compresses the service needs, though in the third and fourth year of that computer purchase, availability of parts becomes an issue. Campuses that are already exhibiting the support service crisis are hesitant to add several computer models to their list of supported equipment. More and more ubiquitous computing campuses are fine-tuning their programs to reflect the types of educational technology use that faculty and students expect and the level of support

Colleges and universities that have mature ubiquitous computing programs have had to implement self-sustaining financial environments.

that the institutions can realistically maintain.

Funding

Funding is a concern for ubiquitous ventures, as it is for any technology venture in higher education. Colleges and universities that have mature ubiquitous computing programs have had to implement self-sustaining financial environments, often moving away from the startup or grant funding used in the beginning stages of their programs. Administrative support for these programs is imperative and is a common component across ubiquitous computing campuses. The programs are pervasive and tend to become a way of life among students and faculty. Having "anytime, anywhere" access is not an optional benefit of the program; Internet access is expected to be delivered at dial-tone reliability—to be available as reliably as a telephone connection. To maintain this level of service, institutions must give special attention to continuing the necessary financial support.

Most ubiquitous computing programs today are based in either the library or the computing/information services area of the institution, though these two areas have converged on some campuses. Electronic library resources are imperative to a successful program; these resources should directly support faculty and their integration of digital technologies into traditional courses. Successful ubiquitous programs incorporate the necessary information resources, infrastructure, and hardware, software, and support for faculty to be able to enhance their courses and their teaching style so that student learning is advanced by the newly available ubiquitous computing tools.

Thoughts about the Future

Higher education's obsession with ubiquitous computing is dissipating. The novelty is fading, and campus conversations about computers are diminishing as the computer takes its place with electricity, blackboards, telephones, and libraries as a reliable, always-available intellectual utility.

The future of higher education is about learning strategies. Ubiquitous computing enables teaching and learning that is more interactive, more collaborative, more customized. From the mass production of standardized disciplinary majors, student programs are evolving into individually designed sets of courses. Instead of following majors rigidly specified by a departmental faculty, clusters of students request customized curricula and have more voice in who teaches what and when. Curricula and databases are centered on individual students—no longer on colleges and universities.

With customization comes the demise of the textbook. Professors can now more conveniently swap course materials. Syllabi are crafted from "chunks" of materials, individualized to the capacities and objectives of each professor. Courses are neither all face-to-face nor all virtual. Instead, each educational opportunity includes some face-to-face and some vir-

tual experiences. Each student is encouraged to select the type of learning that works best for him or her.

The current challenge in higher education is to transition students from the campus experience to the rest of their lives. While in college, students have read electronic "course chunks," have submitted electronic term papers, and have consulted electronic reference materials that—without special effort—will soon be lost to them. Unlike college students from previous generations, they will not have on their bookshelves a Shakespeare book, for example, kept from their college days. There is an urgent need to fill this gap, a need that is being pursued by the e-portfolio movement.[5]

An equal challenge is to provide, after graduation, continuing access to the intellectual tool itself. On ubiquitous computing campuses, students learn how to complete intellectual tasks in an environment where computing and the Internet are taken for granted. These students become computer-dependent, just as many Americans become automobile-dependent. Students are able to perform higher-ordered, more complex intellectual tasks because they routinely use computers; yet those same students are often unable to complete even simple tasks without a computer. If students' capacity to take these higher-ordered skills into life is to be sustained, colleges and universities must ease the transition into the years immediately after college. Institutions can do so by enabling students to carry with them the computer they have relied on in college and by facilitating, through alumni offices, the continuation of friendship and learning groups after graduation.

Colleges and universities need to realize that they are leading a cultural revolution. The ubiquitous computing that has become so familiar on many campuses will soon be spreading to secondary schools, then to businesses, and finally to entire communities. The lessons learned at ubiquitous computing campuses will be a rich resource for the building of whole societies based on continuous, appropriate access to the Internet by all.

Notes

1. Shouping Hu and George D. Kuh, "Computing Experience and Good Practices in Undergraduate Education: Does the Degree of Campus 'Wiredness' Matter?" *Education Policy Analysis Archives* 9, no. 49 (November 24, 2001), <http://epaa.asu.edu/epaa/v9n49.html> (accessed March 16, 2003).
2. See the table at <http://www.wfu.edu/administration/ir/docs/CSEQComparison2002.pdf> (accessed March 16, 2003).
3. About two-thirds of these contacts are from visits to our own campuses by representatives of colleges and universities considering a ubiquitous program. Ubiquitous computing campuses have formed a very important network in which they learn from the successes and failures of other institutions, thereby making the facilitation of ubiquity less painful for everyone. Part of what we do, through national and regional meetings and one-on-one consultations with individual campuses, is to serve as facilitators of the communication among various campuses.
4. David G. Brown, ed., *Ubiquitous Computing: The Universal Use of Computers on College Campuses* (Bolton, Mass.: Anker Publishing Co., 2003). The listing of lessons learned is reproduced, from pp. 9–13, with permission from Anker Publishing. For information about the book, see: <http://www.ankerpub.com/books/brown_uc.html>.
5. For more information, join the EDUCAUSE NLII Electronic Portfolios Virtual Community of Practice at <http://www.educause.edu/vcop/eport/>.