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1. New Technologies in Teaching and Learning

The next several years will mark a transition in the format of teaching, a transition marked less by revolutionary changes in technology and more by an exploitation of the potential that current technology developments afford to support learning in more heterogeneous settings. Computing power will continue to grow enormously. In fact, it appears that Moore's law was conservative. Even without the radical chip-fabrication breakthroughs that loom on the horizon, processor speeds of 10 GHz are already being produced in test quantities.[1] Yet the sheer power of computation does not link closely with changes in teaching. Today's laptops can present extraordinary visualizations of electromagnetic force fields, for example, but this graphic power does not necessarily improve students' conceptual understanding of physics. It takes someone—some faculty member—to integrate this capability appropriately into an instructionally meaningful classroom experience.

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Needed: Creative Teaching & Commitment

By Phillip D. Long

Where technology can change classroom teaching is at the intersection between distinctive teaching methods and interesting software tools. For instance, various forms of peer instruction have been around since the late 1990s.[2] These techniques rely on having students interact around key concept questions, to motivate their thinking and to provide the faculty member with real-time feedback on the students' understanding of the problem. The only "technology" needed is colored paper and an overhead projector. Yet there is added richness in the data when the faculty member can see more than a sea of color in response to a multiple-choice question. Classroom feedback tools such as PRS (Personal Response System, <http://www.educue.com/Home.htm>) are thus useful when the instructional approach solicits structured feedback.

It seems more likely that future changes in classroom teaching will come from the technology that students bring with them or have easy access to, rather than from redesigns of the fundamental classroom infrastructure. Those who have experience in "laptop university" programs are quick to say that something intangible seems to happen when the technology is always available. Clearly, better evaluation research is needed to help us understand what that "something" is, but it is worth noting that increasingly, students at most major institutions are entering with their own computers, whether recommended or not.

If personal access to technology is critical, what changes are in store in how the interaction is mediated? There have been various attempts at making the human-computer interface more natural. The most common activity in the classroom is writing. This most basic of activities, the transcription of information, may soon be transformed by some radical technology developments. Two approaches—an optical digital pen and a motion-detection digital pen—are in prototype stages today.[3] In addition to capturing material digitally, these tools separate the capture process from the computational engine, letting the user transfer written notes to a computer at some later, convenient time. The result? Digital pen technology may reintegrate the process of writing and computing.

Personal access is also a function of having the information you want where and when you want it.[4] This can be accomplished by comfortably wearing computational tools (see, e.g., <http://www.media.mit.edu/wearables/>) or by being able to access data, applications, and software environments through widely available, standard input/output stations.[5] The next "new thing" in teaching and technology may not emerge from the technology at all but rather from how we, as active biological agents, weave the technology into the fabric of our institutions, reframing the fundamental questions underlying why and how we teach.

2. Return on Investment

Colleges and universities are some of the most conservative institutions in human culture—and for good reason. The critical questioning of new ideas, technologies, and activities prevents us from bouncing from one harebrained idea to another. It also protects us from political and social pressures to conform to prevailing majority opinions. Yes, such questioning can also be frustrating, since it subjects some

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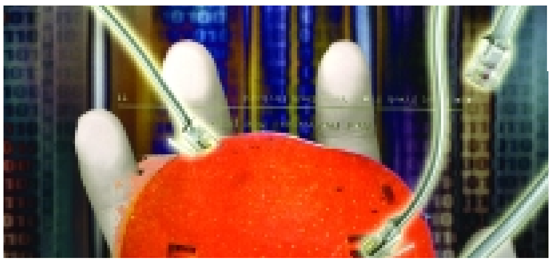


ideas to extraordinarily difficult criteria before transformation can occur. Nevertheless, this conflict is valuable and the resulting intellectual activity essential.

Higher education sits in a cultural context. One measure of our society is the degree to which the pursuit of truth informs and enriches our understanding and experience of our culture. To borrow the motto from my alma mater, Cowell College at the University of California–Santa Cruz: Higher education is "the pursuit of truth in the company of friends." If the culture has moved to adopt technology in commerce, in industry, in recreation, and in daily life, higher education may be legitimately slow to react, but react it must.

The perception that technology has not influenced teaching and learning needs to be examined. This perception reminds me of a story told by my colleague Steve Ehrmann, vice president of the TLT Group and director of the Flashlight Project (http://www.tltgroup.org/). Steve was visiting a college, with well-distributed computer access, to look at how technology influenced instruction. When he asked faculty what, if anything, they had noticed about changes in their teaching, many noted that they were no longer afraid to ask students to revise written assignments, since the computer made revisions easy to do. The corollary of this idea was heard from one of the students, who said, "It's not one's first draft or thought that matters, but the final version." Later, when the college's technology and educational leaders heard these statements, they were stunned. They had not perceived the transformation occurring around them. As Steve observed from this experience, the cumulative effect of individual technology choices made by faculty and students can be significant yet still remain institutionally invisible.[6]

Other examples of the effect of technology in higher education abound, though they are often less striking than the apparent size of our investments in technology. But the return-on-investment question is comparative. It suggests that if the investments had been made in areas other than technology, the returns would be greater. Of course, this begs two questions: In what other areas would this money have been invested, and how are the returns measured? It's an axiom of evaluation research that the trick in understanding the impact of an intervention or change of any sort is to first ask the "right questions." Do we expect grades to go up with the introduction of computers? Will students finish their undergraduate careers in three years instead of four? Will the class section taught with technology learn more than what is learned by the section taught without technology? Are we really teaching the same way in both sections? (If we are, then the ability of the technology to leverage learning is being ignored; if we aren't, then we're comparing apples and oranges.)

We have indeed failed to achieve return on our investment in several key areas, one of which is the increasing proliferation of course management systems (CMSs). Perhaps the problem is that we are using the wrong term. We use "CMSs" to describe the tools that enable faculty to supplement classroom instruction with organized online resources. The problem is that faculty utilize CMSs not just to manage their courses but also to teach their courses. Therein lies the concern: CMSs don't provide tools for building learning exercises that convey a pedagogy at all. The missing element is an online environment that supports the construction of tools that reflect different teaching styles or different disciplinary perspectives.

We're still in the early stage of this transformation of teaching with technology. One effort now under way to confront this problem is the Open Knowledge Initiative, or OKI (http://web.mit.edu/oki). The framework being built is, among other things, a software-development environment to support the creation of authoring tools that need not be generic but that can reflect the values and theoretical perspectives of specific learning approaches. When all content is static, a word processor does a flexible job of creating text. Likewise, a Web authoring tool like Dreamweaver is good for building Web pages. But neither is adequate for developing interactive educational experiences that embody particular teaching processes—for example, active learning exercises in chemistry or reflective learning exercises in literary criticism. There is a potentially enormous return on investment waiting to be reaped here.

3. Mobility and Wireless

Laying a wireless network on top of a fixed network infrastructure provides the "anywhere" in "anywhere, anytime" computing. As in all other infrastructure transitions, however, we must be extraordinarily prescient and lucky in our planning in order to avoid costly mistakes. Old buildings present expensive challenges to wireless deployment, for instance, since buildings that have radio-opaque construction materials make the placement of access points difficult. The deployment of wireless technologies across buildings of various ages thus results in widely varying costs—raising potential issues of equity if these costs affect where the wireless ultimately gets installed.

Enabling wireless access literally changes behavior. With wireless access, faculty who teach current events face students who have CNN.com in one window of their laptops and the *New York Times* in another. A business school faculty member noted that he used to feel comfortable reading the *Wall Street Journal* before attending class but that now he asks his students for stock and business updates *during* class to stimulate discussion around the topics he is presenting.

Wireless access also challenges the perception of what students can and should be doing in class. Students are able to watch and listen to the faculty member's lecture while also looking at the cartoon network, or sending instant messages to friends back in the residence hall, or downloading MP3s. Are students' attention spans developed enough to resist the temptation to surf the Internet during a lecture? Is it the faculty member's place to constrain, scaffold, or otherwise shape the learning environment to focus students' attention on learning during class? Are we really dealing with a new phenomenon, or are we simply encountering wandering attention spans more overtly?

Wireless networking is undoubtedly enabling communication. What we do with wireless communication is the real issue. So far, our thinking has been confined to having wireless replace wires, and the devices at either end are only modestly different. Our imaginations need to be exercised to step up to the possibilities offered by connection without boundaries. In doing so, we must remember that this is a novel environment. We tend to think of increasing connectivity as uniformly "good." But we must question our assumptions. Are there places where we want to remain technologically *dis*connected?

4. The "Information Grid"

The information grid is spanning the distance between work and higher education. The interconnection offered by enveloping our lives in a surround of cyberspace provides a bridge that we are only starting to use. We see its impact in the emergence of distance education, providing new learning opportunities for working adults. We see it in the numbers of college alumni being "brought back" to campus electronically to take courses that they can use in their professions. We see it in the integration of campus research projects with research efforts in corporate and government labs.

The key to this synergy is its bi-directionality. Whereas the power grid creates energy at power plants and transmits that energy to consumers, the information grid allows everyone to both create and consume knowledge. Anyone connected to the information grid can both contribute and learn. This was one of the critical factors that fed the growth of the Internet. And it is one of the endangered attributes of the information grid of today and tomorrow.

As we transition from the populist origins of the Internet to a corporate-managed information grid, we enable the structures of these corporate institutions to impose their behavioral rules. A corollary of successful commercialization is predictable stability achieved through control. In the early days of the Internet, cyberspace was hailed for overcoming geopolitical boundaries. It didn't matter where you were: the network carried your message and your ideas and let you exchange them freely with others. The free exchange of ideas permitted new thoughts, or memes, to reach those unfamiliar with them.

Today, the unrestricted exchange of memes is being challenged by governments, municipalities, and corporations threatened by the process. The development of geo-location tools for the Internet is enabling the restriction of information flow. Soon, those who manage networks will be unable to filter packets based on geographic origin. The application of this ability has potentially startling consequences. Since some U.S. towns prohibit the sale and consumption of alcohol, might the distribution of information about alcohol be similarly restricted in these locations? If a book is published in the United States and sold on Amazon.com, might the publisher find it useful to restrict its sale to certain countries until translations are available?

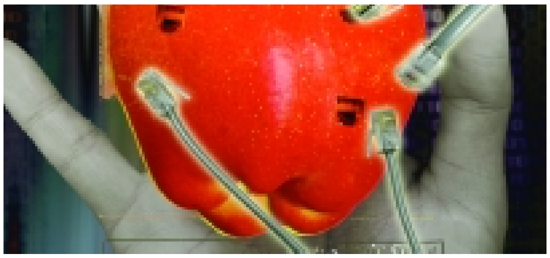
How the information grid behaves—the rules that govern it—will be a reflection of the decision made in the code that runs it. This code will define whether the information grid retains the vision and equality that were hallmarks of its formation or whether it will be transformed into the power grid of directed rules and one-way flow of information.

5. Leveraging Technology for Teaching

My advice for leveraging technology for teaching consists of six suggestions: (1) solve the access problem; (2) provide distributed support; (3) utilize students; (4) follow software standards; (5) consider open-source solutions; and (6) digitize campus intellectual output.

1. Solve the access problem. Before the fruits of technology can be harvested for teaching and learning, the fundamental prerequisite of easy, convenient, and anytime access for all students must be achieved. The strategies used to achieve this prerequisite vary widely, from equipping all incoming students with their own computers, to assisting students in purchasing computers themselves, to making public access pervasive on campus—in residence halls, in the library, and in the coffee shops of the student center. However the challenge is met, access for all must be achieved because a faculty member considering using technology in his or her class must be able to do so without worrying that a subset of students will be unable to perform the work. It is unreasonable to expect faculty to embrace technology if in doing so they discriminate against students who cannot participate in this form of learning.

2. Provide distributed support that leverages teams for coordinated help. Leverage support to provide the right skills in the right combinations. Faculty are discipline experts, with research and/or teaching skills that have been developed through years of professional engagement. Some may also be technology experts, programmers, instructional designers, and network engineers, but that is not their profession or, in most instances, their avocation. Nor should it be. Support



must be available to maximize the contribution that faculty are best able to make. In most instances, the support that faculty need must be local. Unless an institution is very small (not just in headcount but in physical size), it is unrealistic to expect faculty to go to a central location for their support. Rather, the support must be able to engage them not only where they are most comfortable but also with some knowledge of the domain in which they work. This implies that support teams assist faculty in transforming the material (content) and the teaching style (learning design) into meaningful combinations of technology-enabled activities. It also means that support teams should understand where the technology is best *not* applied and should be willing to say

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so. To the vast majority of technologists, everything can be improved with technology—all problems look like nails to someone wielding a hammer. Reality is more complex and subtle. Resist the temptation to engage technology in the solution for the sake of technology (or for justifying an imaginary return on investment). Faculty technology support needs three elements: distributed consultation, an effective and simple point of first contact, and a mechanism for the local delivery of the required help. Look at your processes for providing faculty support, and if you're missing any one of these three elements, address the problem.

3. Utilize your renewable resources: students. Recognize that the greatest technological resource of most colleges and universities is renewed every fall with the next incoming cohort of ever more technologically sophisticated students. Engaging students as colleagues to provide technology support—whether through peer-to-peer consultation or as technology assistants to faculty—can be an effective way to provide additional help as well as to give students useful professional experience.

4. Follow recognized, community-derived software standards. Look for technologies and software that follow broadly recognized standards such as those promoted by the IMS Global Learning Consortium, Inc. (http://www.imsproject.org/). Adhering to IMS-standards in technology development separates the manufacturer or producer of hardware and software from the problem toward which it is applied and gives an institution a greater likelihood of achieving interoperability and portability of applications in the face of continuing technology change.

5. Consider open-source solutions. Look carefully at open-source software solutions before jumping to vendor-specific approaches. The open-source software movement is gaining credibility and respect from the value of some of its flagship efforts such as Linux. Open-source development is occurring in a variety of areas that are crucial to the future technology directions of colleges and universities: portals, with the uPortal effort (http://mis105.mis.udel.edu/ja-sig/uportal/); learning management systems, with the Open Knowledge Initiative (http://web.mit.edu/oki/); and content repositories, with MERLOT (http://www.merlot.org/Home.po) and the MIT OpenCourseWare initiative (http://web.mit.edu/ocw/). Often, open-source efforts are discounted because their support comes from a community of volunteers. Many people implementing technology solutions say they prefer to have a business standing behind the product, with a 1-800 number to call for help. Just remember the volatility of the technology business. Would you rather own the code and engage with a committed community of colleagues, or would you prefer to buy code that you cannot manipulate and then simply hope that the business remains both solvent and committed to developing the product in the direction of your needs?

6. Capture and maintain the institution's intellectual output in digital format. The source content for learning management systems, for library reserves, and even for juried journals should be digital. Encourage the digital creation of material to avoid having to convert everything. Provide simple mechanisms for easily converting material that was not created digitally. Look to digital-repository projects for guidelines and ideas about how to manage and archive digital objects on an institutional scale.[9] At the same time, develop an institutional intellectual property policy that will work for your faculty and institution.

6. Digital Divide

The digital divide is real and pernicious, but it is misnamed. It is an artifact of the general problem of failing to recognize the value of education in our society and failing to invest the necessary resources to provide students with the tools they need to learn and the environment they need to succeed. Yet the problem is far more complex than simple resource allocation. Even if we were able to provide computer technology for all students, from kindergarten on up, many teachers would be at a loss as to what to do with it; for example, there simply are not enough learning programs to complement the learning tools. In addition, the computers would be in schools with insufficient electrical power to turn on the computers without blowing fuses. And they would be in rooms without enough seats for all students to be able to use them.

At wealthier schools, the impact of the digital divide is muted. These students have, in one way or another, acquired or arranged access to the technology they need. Surveys of top private colleges and universities, for example, show that in the freshman class of 2004, more than 90 percent brought a computer with them, despite the fact that hardly any of these same institutions list a computer as a freshman requirement. The vast majority of students are not, however, in the elite private colleges and universities. For these students, access must be provided by other means. Efforts to get technology, from chalk to computers, into schools should be encouraged and supported: recycling programs, foundation grants, nonprofit organizations, and commercial enterprises that financially or materially support the acquisition of technology by schools all help.

Technology is only part of the issue. Technology is a tool to enable learning, but there are other tools that are equally important and that are, in the overall scheme of things, perhaps more central. Good teaching and effective learning can be achieved anywhere there is drive, enthusiasm, and dedication. Computers can expand and enrich the potential for learning, but technology is no substitute for creative teaching and for a commitment to education in families, communities, and school systems.

Notes

1. CPU clock speeds of 10 GHz were reported at the February 2002 International Solid-State Circuits Conference (San Francisco, California). See <http://www.isscc.org/isscc/>.
2. See Eric Mazur, *Peer Instruction: A User's Manual,* Series in Educational Innovation (Upper Saddle River, N.J.: Prentice Hall, 1997); see also <http://mazur.www.harvard.edu/education/pi.html>.
3. A motion-detection digital pen is under development by OTM Technologies: <http://www.otmtech.com/vpen4.asp>. For an example of an optical digital pen, under development by C Technologies and marketed as the Anoto pen, see <http://www.anoto.com/>.
4. Carl Berger, at the University of Michigan, refers to this idea as WINWINI ("What I Need When I Need It"). See Carole A. Barone, "WINWINI and the Killer App: An Interview with Carl F. Berger," *EDUCAUSE Review* 27, no. 2 (March/April 2002): 20–26, <http://www.educause.edu/pub/er/erm02/erm022w.asp> (accessed March 20, 2002).
5. For a prototype personal data-computation device, see the IBM Meta Pad project, <http://researchweb.watson.ibm.com/thinkresearch/pages/2002/20020207_metapad.shtml>.
6. Stephen C. Ehrmann, "Asking the Right Question: What Does Research Tell Us about Technology and Higher Learning?" <http://www.learner.org/edtech/rscheval/rightquestion.html> (accessed March 8, 2002), originally published in *Change: The Magazine of Higher Learning* 27, no. 2 (March 1995): 20–27.
7. See Lawrence Lessig, *Code and Other Laws of Cyberspace* (New York: Basic Books, 1999).
8. See <http://www.tltgroup.org/programs/sta.html> for information on the TLT Group's Student Technology Assistant Program.
9. See, for example, the IMS Digital Repositories Working Group for information about standards (http://www.imsproject.org/digitalrepositoriesteam.html), and see specific projects such as the DSpace initiative (http://web.mit.edu/dspace/live/home.html).