Technology

By James J. Duderstadt

“The impact of information technology will be even more radical than the harnessing of steam and electricity in the 19th century. Rather it will be more akin to the discovery of fire by early ancestors, since it will prepare the way for a revolutionary leap into a new age that will profoundly transform human culture.”

—Jacques Attali, Millennium: Winners and Losers in the Coming World Order (1992)

Reprinted with permission from James J. Duderstadt, A University for the 21st Century (Ann Arbor: University of Michigan Press, 2000). Dr. Duderstadt is President Emeritus and University Professor of Science and Engineering at the University of Michigan. He also serves as Director of the Millennium Project, a research center concerned with the future of higher education.

If there was one sector that most strongly determined the progress of the twentieth century, it was transportation and its related industries—cars, planes, trains, oil, space. Transportation determined prosperity, national security, even our culture, with the growth of the suburbs and international commerce and culture—and, coincidentally, created the vast wealth to build America’s great universities.

Things are very different today. We have entered a new era in which the engine of progress is not transportation but communication, enabled by the profound advances we are now seeing in computers, networks, satellites, fiber optics, and related technologies. We now face a world in which hundreds of millions of computers easily can plug into a global information infrastructure. These rapidly evolving technologies are dramatically changing the way we collect, manipulate, and transmit information. They change the relationship between people and knowledge.

From a broader perspective, today we find a convergence of several themes: the importance of the university in an age in which knowledge itself has become a key factor in determining security, prosperity, and quality of life; the global nature of our society; the ease with which information technology—computers, telecommunications, and multimedia—enables the rapid exchange of information; and networking—the degree to which information collaboration and communication among individuals and institutions are replacing more formal social structures, such as governments and states. We are also seeing a convergence of technology as the television becomes a computer and hence a window into the Net. As a result, there is also a convergence in which computer, telecommunications, entertainment, and commerce are merging into a gigantic, $1 trillion “infotainment” market value.

Earlier we suggested that knowledge was both a medium and a product of the university as a social institution. Since information is the raw material for knowledge, it is reasonable to suspect that a technology that is expanding our ability to manipulate information by orders of magnitude every decade will have a profound impact on both the mission and the function of the university.

The University as a Knowledge Server

One frequently hears the primary missions of the university referred to in terms of teaching, research, and service. These missions can also be regarded as simply the twentieth-century manifestations of the more fundamental roles of creating, preserving, integrating, transmitting, and applying knowledge. If we were to adopt the more contemporary language of computer networks, the university might be regarded as a “knowledge server,” providing knowledge services (i.e., creating, preserving, transmitting, or applying knowledge) in whatever form needed by contemporary society.

From this more abstract viewpoint, it is clear that while the fundamental knowledge server roles of the university do not change over time, the particular manifestation of these roles do change—and change quite dramatically in fact. Consider the role of “teaching” that is, transmitting knowledge. Although we generally think of this role in terms of a classroom paradigm, that is, of a professor teaching a class of students, who in turn respond by reading assigned texts, writing papers, solving problems or performing experiments, and taking examinations, it is clear that today’s generation of students may demand a quite different approach.

We noted earlier that today’s plug-and-play generation will likely demand that the university replace the classroom lecture with highly interactive and collaborative experiences.

It could well be that faculty members of the twenty-first-century university will find it necessary to set aside their roles as teachers and, instead, become designers of learning experiences, in which students tend to learn primarily on their own through reading, writing, and problem solving. Instead, they may be asked to develop collaborative learning experiences in which students work together and learn together, with the faculty member becoming more of a consultant or a coach than a teacher. Faculty members will be less concerned with identifying and then transmitting intellectual content and more focused on inspiring, motivating, and managing an active learning process by students. Of course this will require a major change in graduate education, since few of today’s faculty members are taught these skills.

One can easily identify similarly profound changes occurring in the other roles of the university. The process of creating new knowledge is evolving rapidly away from the solitary scholar to teams of scholars, often spread over a number of disciplines. The use of information technology to simulate natural phenomena has created a third
modality of research, on par with theory and experimental work. Even the nature of knowledge creation is shifting somewhat away from the written text, dynamic images, voices, and instructions on how to create new sensory environments.

Technology such as computers, networks, high-definition television, ubiquitous computing, knowbots, and other technologies may well invalidate most of the current assumptions and thinking about the future nature of the university.

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Some Operational Issues for Universities

All universities face major challenges in keeping pace with the profound evolution of information and its implication for their activities. Not the least of these challenges is financial, since as a rule of thumb most organizations have found that staying abreast of this technology requires an annual investment of roughly 10 percent of their operating budget. For a very large campus such as the University of Michigan, this can amount to hundreds of millions of dollars per year.

But there are other challenges. Many universities are simply unprepared for the new plug-and-play generation, already experienced in using computers and net-savvy, who will expect—indeed, demand—sophisticated computing environments at college. More broadly, information technology is rapidly becoming a strategic asset for universities, critical to their academic mission and their administrative services, that must be provided on a robust basis to the entire faculty, staff, and student body.
In positioning themselves for this technology, universities should recognize several facts of contemporary life. First, robust, high-speed networks are becoming not only available but also absolutely essential for knowledge-driven enterprises such as universities. Powerful computers are available at reasonable prices to students, but these will require supporting network infrastructure. There will continue to be diversity in the technology needs of faculty, with the most intensive needs likely to arise in parts of the university such as the arts and humanities where strong external support may not be available.

Historically, technology has been seen as a capital expenditure for universities or as an experimental tool to be made available to only a few. In the future, higher education should conceive of information technology both as an investment and a strategic asset that will be used by the entire faculty, staff, and student body to sustain and enhance the mission of the university. The following are some possible guidelines for such investments, gleaned from many years of experience at Michigan and other universities.

Invest in “Big Pipes” While the processing power of computers continues to increase, far more importance to universities is the increasing bandwidth of communications technology. Both Internet access to off-campus resources and “intranet” capability to link students, faculty, and staff together are the highest priority. The key theme will be connectivity, essential to the mission of the university. The following are some of the highest priority departments:

- **In the future, higher education should conceive of information technology both as an investment and a strategic asset that will be used by the entire faculty, staff, and student body to sustain and enhance the mission of the university.**

- **Strive for Multi-Vendor Open Systems Environments** Universities should avoid hitching their wagons to a small set of vendors. As information technology becomes more of a commodity marketplace, new companies and equipment will continue to appear. The great diversity in needs of various parts of the university community also will demand a highly diverse technology infrastructure. Universities will seek robust network access to digital libraries and graphics processing. Scientists and engineers will seek massively parallel processing. Social scientists will likely seek the capacity to manage massive databases, for example, data warehouses and data mining technology. Artists, architects, and musicians will require multimedia technology. Business and financial operations will seek fast data processing, robust communications, and exceptionally high security.

- **Linking these complex multi-vendor environments together will be a challenge, since they use different equipment, diverse software and operating systems for varying purposes. For this reason, it is important to insist on open-systems technology rather than relying on proprietary systems. Fortunately, most information technology is moving rapidly away from proprietary mainframes (“big iron”) to client-server systems based on standard operating systems such as Unix, Linux, or Windows-NT. There is a vast array of commercial off-the-shelf software available for such open systems.**

- **As digital technology becomes increasingly ubiquitous, universities will have to make intelligent decisions as to just what components they will provide and which should be the personal responsibility of members of the community. While networks and specialized computing resources will continue to be the responsibility of the university, the purchase of other digital devices such as personal communicators will almost certainly be left to the student, faculty, or staff member.**

- **Universities will need to strive for synergies in the integration of various technologies. Beyond the merging of voice, data, and video networks, there will be possibilities as well to merge applications across areas such as instruction, administration, and research. The issue of financing will become significant as institutions seek a balance between institution-supported central services and point-of-access payments through technologies such as smart cards.**

**Student Participation**

There continues to be a debate about whether students should be required to purchase their own computers. Student experience with and their access to information technology is evolving rapidly. In 1997 surveys, the University of Michigan found that 75% of students had Internet access of some sort at home, and 60% of these students used the Internet at least once a week. In 2000, 95% of incoming students had access to the Internet at home. The University of Michigan has set a goal of having all students with computer access in their residence halls by 2002.

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of Michigan found that over 90 percent of its first-year stu-
dents arrived on campus with at least three years of com-
puter experience, and essentially all graduating seniors indicated they made extensive use of computers during their education. Over 60 percent owned computers when they first arrived on campus, and a far higher percentage owned personal computers by the time of grad-
uation. Our students currently spend about twelve to twenty-four
hours a week on a computer, with roughly half of this on
the Net. By way of comparison, faculty members indi-
cated that they spend about twenty hours a week working
on computers; a significant fraction of this work was
done at home. Over 90 percent of the faculty have personal
computers.

Universities should be prepared to support the personal
computing needs of students by providing robust network
linkages both in residence halls and student commons areas. They should negotiate with community telecommu-
nications companies—both telephone and cable television
companies—to facilitate off-campus communications,
while at the same time providing sufficient network
communication ports to facilitate off-campus students.

The role that universities can play in negotiating dis-
counts with hardware manufacturers for student personal
computers is more controversial. Local retailers complain
that this represents unfair competition (although, in reality,
most will benefit significantly from consequent software
and peripheral sales). It is my belief that universities have an
obligation to assist students in acquiring the hardware and
software that have become essential for their education.

As personal computer technology saturates the student
body, universities should continue to build and maintain
public computer sites where students can have access to
more powerful technology. In a very real sense, these com-
puter cluster sites are becoming analogous to the role that
libraries played in the past. They provide students with the
access to knowledge necessary for their studies, as well as
places to study, gather, and collaborate.

Cultural Issues
Although making the necessary investment in the technol-
ogy infrastructure and support services will strain univer-
sity budgets, the most critical challenges may involve the
culture of the university. We have already noted that there
will be great diversity in the technology needs of various
disciplines and programs, and these needs will likely not be
aligned with financial resources. There is an important
strategic issue facing most universities: Should the evolu-
tion of information technology be carefully coordinated
and centralized or allowed to flourish in a relatively uncon-
strained manner in various units? Perhaps because of our
size and highly decentralized culture, at Michigan we have
long preferred a “Net every flower bloom” approach. We
have encouraged islands of innovation, in which certain
units are strongly encouraged to move out ahead to explore
new technologies. This has allowed some programs to
move into leadership roles and serve as pathfinders for the
rest of the university.

Another cultural issue involves just who within the univer-
sity community will drive change. Many of our en-
tering students—and soon, possibly most—have computing
skills far beyond those of our faculty. Our experience tells
us that it will not be the faculty or staff but rather the
students themselves that will lead in the adoption of new
technology. As members of the digital generation, they are
far more comfortable with this emerging technology. They
are a fault-tolerant population, willing to work with the
inevitable bugs in “Version 1.0” of new hardware and
software.

Although information technology today is used primar-
ily to augment and enrich traditional instructional offer-
ings, over the longer term it will likely change the learning
paradigm. It will likely change the methods of scholarship.
And it will certainly change the relationship between fac-
ulty and staff and the university. For example, as the univer-
sity is viewed increasingly as a “content provider,” with the
evolution of the commodity classroom, learning ware, and
the like, we will need to rethink issues such as ownership of
faculty course materials.

As one example of this phenomenon, many students are
already moving rapidly to embrace Net-based learning and
take increasing control over their own education. They are
still enrolling in traditional academic programs and partici-
pating in time-tested pedagogy such as lecture courses.
homework assignments, and laboratory experiments. But many students approach learning in very different ways when they work on their own. They use the Net to become “open learners,” accessing worldwide resources and Net-based communities of utility to their own learning objectives.

What about productivity? Information technology can certainly enhance the quality of academic programs. But extensive experience in the private sector has suggested that this technology is able to improve productivity and lower costs only if the fundamental process of work itself is reengineered. In other words, before we can achieve an economic benefit from this technology, we must first reexamine our current paradigms for teaching and learning.

As the constraints of time and space—perhaps even reality itself—are relieved by information technology, will the university as a physical place continue to hold its relevance?

In the near term it seems likely that the university as a physical place, a community of scholars and a center of culture, will remain. Information technology will be used to augment and enrich the traditional activities of the university in much its traditional forms. To be sure, the current arrangements worldwide of higher education may shift. For example, students may choose to distribute their college education among residential campuses, commuter colleges, and online or virtual universities. They may also assume more responsibility for and control over their education. In this sense, information technology is rapidly becoming a liberating force in our society, not only freeing us from the mental drudgery of routine tasks, but also linking us together in ways we never dreamed possible, overcoming the constraints of space and time. Furthermore, the new knowledge media enables us to build and sustain new types of learning communities, free from the constraints of space and time.

But it also poses certain risks to the university. It will create strong incentives to standardize higher education, perhaps reducing it to its lowest common denominator of quality. It could dilute our intellectual resources and distribute them through unregulated agreements between faculty and electronic publishers. It will almost certainly open up the university to competition, both from other educational institutions as well as from the commercial sector.

It is our collective challenge as scholars, educators, and leaders to develop a strategic framework capable of understanding and shaping the impact that this extraordinary technology will have on our institutions. We are on the threshold of a revolution that is making the world’s accumulated information and knowledge accessible to individuals everywhere, a technology that will link us together into new communities never before possible or even imaginable. This has breathtaking implications for education, research, and learning that cannot be ignored by the university.

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Notes
4. For an excellent introduction to scenario planning in this area, see the website (http://www.siamachs.umd.edu/2010) for the Vision 2010 project, directed by Daniel E. Atkins and sponsored by the Carnegie Foundation for the Advancement of Teaching.
5. For information concerning the Internet2 project, see the website for the University Corporation for the Advancement of Internet Development at (http://www.internet2.edu/).
6. Student-Faculty Computer Survey, Information Technology Division, University of Michigan, Ann Arbor, 1997.

San Antonio, with its vibrant River Walk, provides an outstanding venue for a new EDUCAUSE regional conference. Technologists, managers, and executives from all institutions—large and small, public and private—are invited to attend.