

By Shirley Ann Jackson

# AHEAD OF THE CURVE

## FUTURE SHIFTS IN HIGHER EDUCATION

It used to be that physicians stayed “ahead of the curve” with new research in their specialties by reading medical journal articles. Yet medical literature databases today house more than 10 million abstracts and are adding 7,000 to 8,000 more each week. Staying ahead of the curve is thus impossible for any single individual to manage. Further, synthesizing that volume of literature—which could yield new research paths and new medical breakthroughs—is simply beyond the capability of individual human beings, who read an average of sixty pages per hour. Such synthesis is even beyond the capability of a team of individuals. Enter text-mining—software that will “read” 250,000 pages an hour, scanning reams of documents, categorizing information, and making links and visual maps that can lead researchers in directions they might not have considered without the use of the software.<sup>1</sup>

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Reading and synthesizing medical journals for possible research trajectories is but a single example of the innovations that are transforming science and technology. These innovations are the direct result of a complex combination of forces at work in a new environment, encompassing education, research, opportunity, challenge, ingenuity, creativity, and imagination. Innate ingenuity, powered by higher education and experienced in advanced research, is driving vast and swift advances and innovations—changes that are transforming the world as we have known it. That transformation is occurring perhaps more swiftly than we even realize. Herein lies our challenge.

This new world is global and multidisciplinary. It is evolving new configurations and relationships between and among nations, peoples, cultures, philosophies, values, and governments. No longer is the United States, for example, contending with a single geographic adversary, as was the case throughout the Cold War. The new “opponents” are what we might call “threats without borders”: SARS, AIDS, forest fires, power blackouts, global warming, species extinction, terrorism, and the myriad challenges of a significant segment of the global population that lacks sufficient food, education, and health care.

These are the challenges that nations and peoples are facing in our young century. To contend with them, and to resolve them, virtually all entities—from governments, corporations, and policy agencies to colleges and universities, professions, and even individuals—are having to devise new strategies, new alternatives, new approaches. Indeed, transformation at some level is the order of the day.

In higher education, the pedagogical, research, and administrative changes necessitated by new technological capabilities and methodologies are profoundly affecting the work and methods of scientists, engineers, educators, and administrators. Colleges and universities *must* evolve to meet the new challenges. Yet while information technology is one of the transformational causes, it is also one of the primary enablers of the needed changes. In fact, a recent federal report begins: “The American imagination,

challenged to invent new technologies to meet vital national needs, launched and powered a digital revolution that ultimately swept around the globe.<sup>2</sup> Further, the National Academies Press publication *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* opens with the following statement: "Information technology (IT) is essential to virtually the nation's entire critical infrastructure."<sup>3</sup> The university is a key element of that infrastructure, and information technology is the leading edge of other technological innovations and scientific discoveries that are changing and challenging the university.

Let us look, for a moment, at the changes that are taking place in science and information technology today. Both are emerging into the era of "convergence of technologies," providing the next generation of discovery and innovation. The nature of the scientific research that achieves the greatest breakthroughs is now largely multidisciplinary, at the interstices where the traditional disciplines meet. Genomics, for example, relies on both biological sciences and computer technology to make the computations needed for gene mapping.

It is beginning to work the other way as well. The cutting edge in computer science research, for instance, is the study of biological systems as models of complexity and communication: "to learn how, and why, living systems naturally organize themselves—and then apply that learning to the world of computing systems." Likewise, nanotechnology enabled the study of shell-creation by mollusks, which led to the creation of transistors ten thousand times thinner than a human hair and a thousand times stronger than steel.<sup>4</sup> The field of pharmacogenomics leverages advances in both molecular diagnostics and information technology to provide for a future of more refined personalized medicine, which will transform the practice of medicine. In the energy sector, if there had been more advanced IT control systems in the national electrical grid infrastructure, could a cascading event such as the blackout in the northeastern United States in August 2003 have been prevented?<sup>5</sup> Could the blackout that affected Switzerland and most of Italy at the end of September 2003 have been

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avoided? Finally, the hurricane season of 2003 highlighted how the ability to track the path of a storm can save lives and property. Using advanced modeling programs, we have transformed our ability to predict storm paths.

How, then, do colleges and universities transform themselves to further such advances? How do we educate the next generation of technological leaders? How do we use such advances?

More than half a century ago, the eminent scientist Vannevar Bush, a pivotal figure in hypertext research, envisioned a machine he called a "memex." He described it as "a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility."<sup>6</sup> Today, high-performance computing, networking, and information management technologies have given us what Bush envisioned, what a recent government IT research and development report calls a "far-reaching support system for human thought."<sup>7</sup> This is what information technology represents—a support system for human thought and human creativity. Since human thought and creativity are the currency of higher education, proper utilization of the ever-growing capabili-

ties of this exceptional support system can be the means of transformation.

This support system will enable the goal of maintaining and infusing a global perspective in all aspects of education. For decades, the trend in both pedagogy and scientific research was specialization—knowing more and more about increasingly focused and more specialized areas. Today the boundaries of specialization are blurring, just as the newer "threats" are becoming borderless. We have a responsibility to take our young people beyond the boundaries—national as well as disciplinary. We must answer simultaneously the questions concerning how to conduct scientific research and why it is important.

We must do a better job of teaching our students, and ourselves, how to be critical analyzers and consumers of information—because information as an enabler has sweeping implications for a knowledge-based institution, which the university surely is. We also must educate our students to work *between* disciplines, to understand the innovative aspects of science, engineering, and technology. The convergence of information technology and biology can be made as exciting to an eighteen-year-old as a trip to Mars. Nor is a Mars space journey out of the question within a few decades, with ever-increasing advances in materials science, propulsion, and computation.

We must examine pedagogical approaches and learning styles—that is, *how* we educate. The four-year-olds who could program the family VCR and who grew up on MTV, videogames, instant messaging, and text- and video-messaging cell phones are now of college age. We must understand their cognition patterns and devise ways of organizing pedagogy to enable them to use their skills and perspectives in yet more creative ways. Clearly, information technology is the tool that can take us beyond the classroom walls—to offer students the kind of interactive, experiential learning to which they have become habituated and to offer such learning in ways that enhance their cognition, their analytical abilities, and their specific knowledge. Simulation of physical phenomena, gaming technology, and tele-presence/tele-immersion (the ability of geographically

dispersed sites to collaborate in real time) are all pedagogical tools that can help us in this task.<sup>8</sup>

What would the demise of the traditional lecture—the verbal imparting of information to a relatively passive audience—portend for the college or university professor? Some say that the role of the faculty member might devolve into that of an educational consultant. In contrast, I contend that this possibility presents faculty with an exciting and stimulating opportunity to rethink, and to reinvent, their functions and responsibilities and their relationships to students.

If we are to prepare our students for leadership in science, engineering, and other disciplines as well, faculty will be the agents. As the store of information available and retrievable continues to increase exponentially, faculty will be the gatekeepers, the advisors, the mentors. *Information* is not necessarily knowledge, and *knowledge* is not always wisdom. The role of discipline-based faculty will be to help students acquire problem-solving skills, to guide them in understanding and identifying which problems are important to solve, and to help them interpret results. A 2002 publication from the National Academies Press, *Preparing for the Revolution: Information Technology and the Future of the Research University*, states: “Faculty may come to interact with undergraduates in ways that resemble how they interact with their doctoral students today.”<sup>9</sup> That is, faculty will migrate away from the tightly scripted, classroom-centered, seat-based form of instruction—the pedagogical model perhaps most threatened by the ubiquitous availability of IT-based services—to a more interactive, coaching approach. The new faculty-student relationship may become

more like the enduring, sometimes life-long relationship that existed in ancient Greece between teacher and pupil.

Technology has a vital role to play not only in improving pedagogical approaches, and in extending the reach and scope of research, but also in facilitating the effective management and governance of the higher education institution. Technology can help—is helping—colleges and universities to streamline, to enhance efficiency and effectiveness, to ease compliance with governmental requirements, and to further communication between and among academics, students, leaders, governments, and the wider world. Text-mining software, not unlike that available for physicians, can help academic and administrative leaders to access, sort, interconnect, and link the disparate information sources essential to the governance of the institution.

*Preparing for the Revolution* warned that information technology is reshaping research universities and urged against complacency in the face of technological developments. The report raised the specter that research universities that did not keep up with technology might not survive. It urged the academy to respond “with carefully considered strategies backed by prudent investments—not just to avoid extinction, but to actively cultivate opportunity.” Finally, the report suggested that research universities adapt their approaches to governance—to react more nimbly and to reconsider the “academic culture that sometimes allows the demand for consensus to thwart action and in which consultation is often defined as consent.”<sup>10</sup>

Nor is the impact of information technology limited to research universities. Wm. A. Wulf, president of the National

Academy of Engineering, notes: “I believe that a more dramatic transformation is about to shake the foundations of scholarship in the liberal arts.”<sup>11</sup> Wulf posits that the availability of such tools as text-mining will help humanists to sort the mass of information sources in their exploration of hypotheses and to visualize relationships among social and cultural phenomena.

Whether in liberal arts or research universities, information technology cannot be simply grafted onto existing plans. It must be an integral part of a new planning process. At Rensselaer Polytechnic Institute, for example, information technology and its uses permeate every aspect of the strategic plan, emphasizing distance learning, collaboration, networking, and other changes that will address the potential of information technology to transcend not only the boundaries of time and space in research but also the walls of the classroom and the limits of administrative processes. Information technology has become a major research thrust for Rensselaer. It is also a key enabler in streamlining administrative functions, allowing a more performance-based approach to university management.

At Rensselaer, we believe that the academic renaissance toward which contemporary colleges and universities and research institutions must strive should encompass the effective use of technology not only in new research fields such as biotechnology, nanotechnology, and multidisciplinary approaches to information technology but also in ways that enrich the learning experience. Recently, Rensselaer broke ground for the Experimental Media and Performing Arts Center, or EMPAC. The creation of EMPAC is a major component of our



commitment to maximize our interdisciplinary potential, to explore where the sciences and the arts intersect, and to create the sort of interactive educational capability to which young people will respond. Sitting at the nexus of technology and the arts, as both an artistic creation platform and a research facility, it will allow artists to use digital and other media to extend their creativity. Concomitantly, it will allow scientists and engineers to extend their knowledge and technology in the pursuit of artistic creativity.

EMPAC is a key element of one institution's approach to the academic renaissance necessary to infuse a spirit of innovation into future generations. The transformation of higher education is daunting enough under the best of circumstances, yet this transformation must be undertaken during a period in which the United States is contending with a quiet crisis not well recognized or understood: *The interest of young people in science and technology is flagging.* The number of students entering U.S. institutions of

higher learning and intending to pursue scientific and engineering studies has been falling. The country is not building a cohort of scientists, engineers, mathematicians, and technologists to replace those who will soon retire.

The current science and engineering workforce in the United States is aging. The number of individuals who hold science and engineering degrees and who are reaching retirement age is likely to triple in the next decade.<sup>12</sup> Congressional testimony by NASA Administrator Sean O'Keefe shortly before the Space Shuttle *Columbia* disaster indicated that 15 percent of NASA scientists and engineers can retire now and that 25 percent can retire in ten years. This especially will affect areas critical to NASA's mission. The same holds true in other federal agencies, in technology-based corporations, and in non-profits.<sup>13</sup>

In addition, the foreign students on whom the United States has come to depend to augment the dwindling supply of new scientists and engineers are no longer coming to the United States—or

staying—in the numbers to which we have become accustomed. Some are seeking their educations in other developed countries because of tightened immigration policies in the United States. Some are staying in their own countries as indigenous educational institutions have grown and strengthened. Increasingly, those who *have* been educated in the United States are leaving for new opportunities in their home countries as other nations quickly and quietly catch up to the United States in areas in which we have excelled in the past.<sup>14</sup>

The situation raises a very basic question: Who will do the science and engineering in the United States in the twenty-first century? If the United States fails to replace its scientific and technological cadre, will we lose our preeminent position in the world—a position that has always been driven by scientific and technological innovation and discovery? Preeminence in science and technology has long established the U.S. global leadership. Now that a single “enemy” nation no longer exists, a legitimate goal of science

and technology in the twenty-first century is to address the “threats without borders,” threats that endanger the planet and its peoples, and to raise the standard of living for a world population that will double by midcentury.

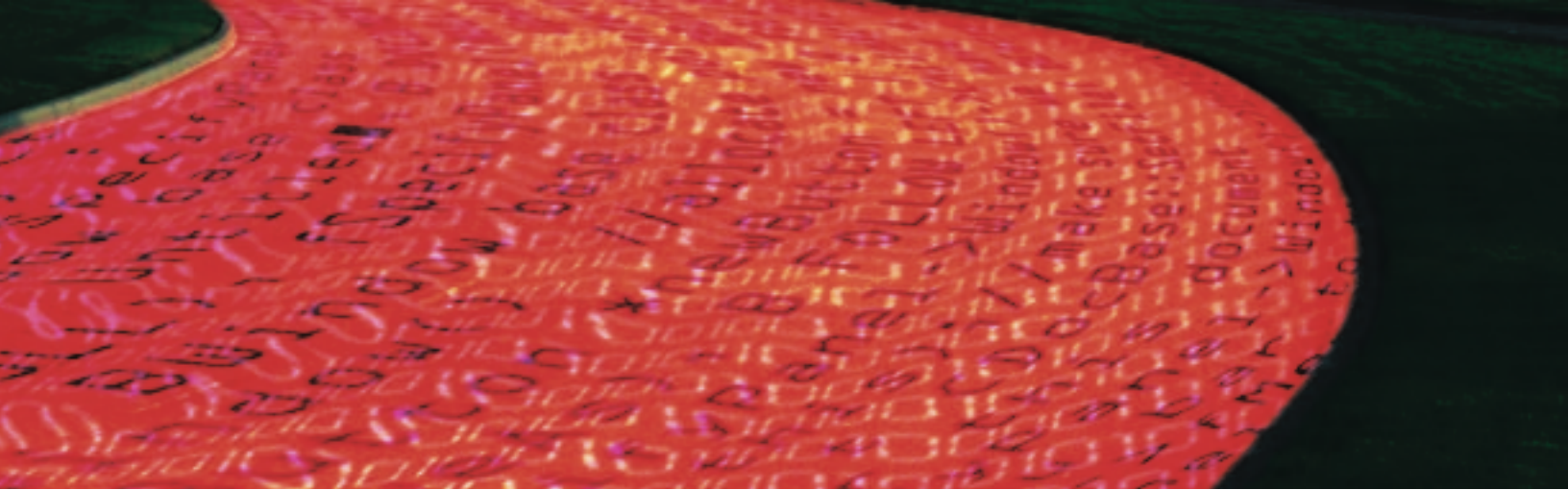
The ability of the United States to fulfill this goal and to compete in the coming decades depends on our young people. In that regard, we have a lot of work to do. The United States is in the middle of the pack among developed nations in measures of secondary and postsecondary educational attainment. The need for academic achievement is particularly acute in the very areas that are most needed to keep pace in a world in which scientific, engineering, and technological expertise is increasingly prized as the ticket to prosperity by awakening giants such as China and India. In 1999, a set of studies known as TIMSS (Third International Mathematics and Science Study) measured the science and mathematics achievement of primary through secondary students in thirty-eight nations. TIMSS showed that whereas U.S.

fourth-graders were close to being the best in the world in the areas tested, U.S. eighth-graders were at or below international averages and U.S. high school seniors were near the bottom.<sup>15</sup> The latest figures from the Organisation for Economic Co-operation and Development (OECD) show that U.S. fifteen-year-olds are no better than *average* in scientific and mathematical literacy and are well below fifteen-year-olds in our main economic competitor countries. This is so despite the fact that the United States spends more than all other countries, except Denmark, at the primary level and more than all others, except Switzerland, at the secondary level.<sup>16</sup> The United States is unequaled in its spending for higher education. The United States is essentially underpreparing students for higher education in science and engineering and is getting less overall for its educational dollars—certainly at pre-collegiate levels.

Lack of preparation may have had an impact on enrollment in U.S. institutions of higher learning. Between 1967 and

1992, overall college and university undergraduate enrollment increased from 7 million to 15 million, but it has remained essentially unchanged since that time. This is partly—but not totally—a function of a decline in college-age population. The decline in population will reverse itself between now and 2010, but not enough to reverse the decline in undergraduate enrollment and graduation in science and engineering. Between 25 and 30 percent of U.S. students enter college intending to major in science and engineering. However, less than half of them complete a science and engineering degree within five years. The noncompletion rate is even higher for minority students and women.<sup>17</sup>

Minorities traditionally have been underrepresented in science and engineering. In 1980, African-American, Hispanic, and Native American students earned less than 8 percent of about 175,000 undergraduate natural science and engineering degrees awarded in the United States. By 1998, these three minority groups earned about 13 percent of the



slightly more than 200,000 degrees in those categories. That is improvement, but it does not represent parity with traditional students, considering that in 1998, minorities represented almost one-third of the twenty-four-year-old population, versus a little more than 20 percent in 1980.<sup>18</sup>

Women also are increasing as a percentage of science and engineering students at all levels, particularly at the graduate level. The latest available figures show that women represent 43 percent of the graduate enrollment in natural sciences. Women in underrepresented minority groups have a higher proportion of graduate enrollment, relative to minority populations, than women in other groups. Half of the African-American graduate students in science and one-third of the African-American graduate students in engineering are women.<sup>19</sup> Overall, however, less than one-fifth of all engineering students are women,<sup>20</sup> whereas in other historically male-dominated fields, such as medicine and law, enrollment has almost reached gender parity.

According to the National Center for Education Statistics, undergraduate enrollment of minority students and women is increasing faster than that of men and white students, and that percentage will continue to increase. According to the report, the proportion of white students dropped by 8.1 percent over the most recent ten-year period. During the same period, enrollment of minority students steadily increased, with minorities making up about one-third of the student population in 1999–2000, compared with only one-fourth a decade earlier (1989–1990).<sup>21</sup> If the United States is to build its population

of scientists and engineers, this is where we must look.

The lack of interest of our young people overall in science, engineering, and mathematics presents the prospect of a downward spiral that particularly would affect leadership in information technology (not to mention in other, undergirding technologies). This situation is exacerbated by the outmigration of certain technology jobs. U.S. firms have moved lower-level IT positions overseas almost since the beginning of the computer revolution. However, now the export of higher-level jobs is becoming a reality.

The *New York Times* recently reported on an internal discussion at IBM during

which top IBM employee relations executives projected that 3 million service jobs would shift to foreign workers by 2015 and that IBM should move some jobs, including software design, to India and other countries. “Our competitors are doing it and we have to do it,” the *Times* quoted an IBM executive as saying. Meanwhile, Andrew S. Grove, Intel cofounder and chairman and one of the founding fathers of the U.S. high-tech industry, recently warned that the United States is “under siege by countries taking advantage of cheap labor costs and strong incentives for new financial investment.” Grove said that India could surpass the United States in software and tech-service jobs by 2010. Grove hinted at the intensity of the coming challenges in the title of his 1996 book: *Only the Paranoid Survive*.<sup>22</sup>

If students already lack interest in science, engineering, and mathematics, and if the number of prospective jobs in science and technology in the United States is diminishing, are young people likely to choose careers in these fields? If skills in this country erode, more such jobs may move offshore—to where the skills are. This represents a spiraling situation that could jeopardize the future prosperity, global preeminence, and even national security of the United States.

What we are really talking about here is not just jobs, but national capacity in critical areas—areas that other countries, both developed and developing, have decided are key to their economic and security futures. Although this commitment of other nations to the development of key enabling capabilities is most strongly expressed in information technology, IT is simply following a path that other disciplines have long trodden. Science is a global enterprise, and it was global long before *globalization*

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became a common term for the growing interdependence and interconnection among the world economies. The Russian dramatist Anton Chekov, who was also a medical doctor and researcher, observed more than a century ago: “There is no national science, just as there is no national multiplication table.”<sup>23</sup>

As a general proposition, the United States gains from the scientific discoveries of other countries. The same holds true for economic development in other countries, as they become markets for U.S. goods and services. Certainly, there are dislocations as jobs migrate, just as there are dislocations when imbalances create trade deficits in the United States. These dislocations, in skilled jobs as well as in trade, will be absorbed, but if the United States is to maintain its lead in innovation—the foundation for its competitiveness—the key is education.

This means educating the under-represented majority, ensuring that they gain a strong grounding in the fundamentals of science and mathematics so that their options are not precluded before they even begin. It further means reaching out to *all* young people to rekindle (or kindle, as the case may be) in them an interest in science, mathematics, and engineering. We must nurture that interest through the use of new pedagogical approaches that employ the best technological innovations in clever ways and that spur young people’s creativity, allowing them to become the next generation of thinkers, discoverers, doers, and problem-solvers.



At this point, there are still more questions than answers about the full impact of information technology in transforming higher education. What will be the roles of non-profit and for-profit online education providers? Should students pursue their degree work only at the institution at which they matriculated, or should they pick and choose among online courses offered by a smorgasbord of colleges and universities? Does it make sense for every institution to support the full complement of disciplines, or should colleges and universities share courses, seminars, discussion groups, and degree programs in cyberspace? In a world in

which knowledge is a commodity, how far should a college or university go in accepting or seeking profit-making ventures? In time, each institution of higher learning will find its own answers to these questions, and more. Each academic institution will formulate its own approach, based on its mission, academic strengths, and specific situation.

What we know now is that we must be prepared for disruption. Technology is disruptive. Information technology is *really* disruptive. Colleges and universities must engage in broad-based, grassroots, deep discussions, must think through the issues and their impact on higher education, and must devote sufficient resources and investment to get ahead of the curve in this new era. With the proper preparation and with the tools of information technology—our “support system for human thought and human creativity”—U.S. higher education institutions can emerge as even more valued contributors to the nation and to the world of the future. *e*

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