The core characteristic of the information revolution is continuous innovation. The information age has wrought radical transformations, displacing the slower, more cumulative change prevalent in times past. Thomas Hughes, Mellon professor emeritus of the history of science at the University of Pennsylvania and distinguished visiting professor at Massachusetts Institute of Technology, recognizes the potential wide-ranging effects of technology on higher education, but cautions that the linear, rational assumptions of technological determinism do not stand the test of time.
Technological Determinism

Enthusiasm for technology-enabled education is spreading in higher education. The enthusiasts often believe in technological determinism and the predictability of technological change. History reveals, however, that the progress of technology is value-laden and human-shaped, making precise predictions impossible. We should be prepared for unanticipated applications of computer and Internet technology to education and realize that the future will be shaped by individuals as well as by technological progress.

While the Internet may “change everything”—and thus we are correctly anticipating momentous shifts—projecting familiar, linear progress into the future is a mistake. The Internet already has generated a technical revolution, and may very well culminate in a “sociotechnical ” revolution. A sociotechnical revolution is a complex phenomenon involving economic, organizational, political, and social transformations that do indeed change everything, including education.

Everything Changes, But Not as Anticipated

Today’s predictions of the future of technology-enabled education are mostly projections of contemporary developments. Yet history suggests that the future will involve computer and Internet applications not anticipated by its present day inventors and developers. The history of technology offers many instances of an evolving technology being applied in ways the original inventors did not foresee. The internal combustion engine, for example, was not originally intended for transportation by its inventors, yet its development eventually led to automobiles and airplanes. Awareness that many technology-enabled education innovations cannot be anticipated should help enthusiasts avoid locking into just those innovations presently available. Early lock-in fosters the constraints of path dependency, the classic example of which is the continued use of the QWERTY keyboard.

Technological enthusiasts and forecasters frequently make the mistake of envisioning scenarios involving logical sequences of social, political, and cultural changes following in the wake of technological change. Although not acknowledged, they presume value-free technological determinism, when in fact their values shape their predictions. Similarly, many university administrators and some faculty envision a technology-enabled education that reinforces their visions and vested interests. That is, they tend toward self-serving technological determinism.

People and their values shape technology, and can effectively delay or even prevent technological change. Today, strong social forces resist the introduction of various types of technology-enabled education. Most people usually oppose machines taking over their roles. Countless faculty members have a vested interest in prolonging face-to-face lecturing and discussion, printed textbooks, small classes and seminars, and individual, faculty designed syllabi. Faculty, in short, resist having their skills devalued.

Massive systems, such as higher education, have characteristics analogous to the physical inertia of motion. Involving a mass of human, technical, organizational, and attitudinal components, higher education tends to maintain steady growth and direction. The huge investment of physical and human resources in education militates against disruptive changes that threaten to devalue the skills of professors and administrators, and to make existing physical plant and equipment obsolete.
Breaking the Momentum: System Builders

How has resistance to technological change been overcome in the past? Often, the leverage for change has been imposed on resisting systems. People with power outside higher education may eventually intervene to overcome resistance to technology-enabled education. In the case of public universities, government authorities often have the power to bring about substantial changes, while boards of overseers have leverage in private universities. Funding agencies in particular, including governments, can also foster change by supporting specific areas of interest.

Among those who effect change, the independent inventors stand tallest. Inventors at the core of the Second Industrial Revolution (1870-1940) included Thomas Edison (electric power), Alexander Graham Bell (the telephone), the Wright Brothers (aviation), and Henry Ford (the automobile). Today’s university researchers are analogous to the independent inventors of the past. They are responsible for a disproportionate number of breakthrough computer hardware and software inventions. Many of them freely choose their research and development problems, and in so doing, differ from researchers in industrial research laboratories.

Following the inventors come the “system builders,” a special breed of managers who have a holistic ability to coordinate the technical and organizational aspects of a sociotechnical revolution. Their genius lies in the integration of heterogeneous physical, human, and organizational components into a productive, goal-oriented system.

A technology-enabled education system of the future may incorporate a research and development organization, a university department, a for-profit software developer, computer Web sites, portals, and a funding organization. The system builder should be capable not only of creating this mix, but also of presiding over, or managing it. Additionally, system builders should be capable of negotiating with political authorities that have the power to influence the sociotechnical system.

Participatory Change

Resistance to disruptive technological change often exists on a deep cultural level that can best be overcome by a participatory approach. Yet today, few faculty are able to perform the complex tasks associated with technology-enabled education, such as placing live lectures and course materials online. In response, universities have established centers staffed by experts who handle the processes associated with technology-enabled education.

The downside of this approach is that professors simply delegate such tasks, and in the process lose control over essential teaching and learning experiences. Meanwhile the experts, driven by technical and economic considerations, tend to overlook other values dear to the faculty.

A better approach would be to encourage or even require faculty participation in the introduction of technology-enabled education. Faculty could assume a hands-on role in the process, working cooperatively with the technology experts to place courses online. To foster positive participation, faculty would become technologically literate through instruction sessions organized by the university.

The participatory approach to overcoming resistance
to change can help obviate the need for outside intervention to move the higher education system toward a technological future.

**Conclusion**

Campus leaders and organizations now dominating higher education may not be those who develop and control technology-enabled education in the future. The providers of gaslight did not introduce electric lighting; the telegraph companies did not take over telephone technology; carriage makers did not prevail in Detroit; and telephone companies did not introduce point-to-point computer network communications. The list of dominant organizations with high momentum failing to introduce the next radical breakthrough in their domain is lengthy.

Campus **leaders** and **organizations** now dominating higher education may not be those who develop and control **technology-enabled** education in the future.

Technological change is usually unpredictable. One sees its future through a glass darkly. The future holds unanticipated applications of present technology, and the introduction of entirely new systems. Those who wish to lead education into a technology-enabled future may have to cast off from their present organizational moorings and launch themselves into a risk filled environment, rich in possibilities to enhance the future of teaching and learning in higher education.

_Thomas Hughes is Mellon professor emeritus of the history of science at the University of Pennsylvania and distinguished visiting professor at the Massachusetts Institute of Technology. His most recent book, _Rescuing Prometheus_ (2000), is about managing the creation of large technological systems. His book _American Genesis_ (1990) was a Pulitzer Prize finalist._