Through a Glass, Darkly

Anticipating the Future of Technology-Enabled Education

By Thomas P. Hughes

A n ever-increasing number of academic administrators, as well as businesspeople, associate technolog-enabled education with the information revolution. They speak enthusiastically of distance learning and of “edtech” firms. Talk about virtual universities has increased. Individualized, active learning is seen as displacing passive learning. Lifelong learning is a common commitment. Rapid and radical change in higher education gathers momentum. Enthusiasm waxes. Many in higher education look forward to being swept along by what they perceive as a mounting technological tide. They expect technology, especially computers and the Internet, to drive changes in the educational system. Based on

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Extrapolation, we should use historical analogies to peer into the future of a sociotechnological system.

By examining the history of various sociotechnological systems, we can suggest, by analogy, the likely future of technology-enabled education. The historian’s task is to choose appropriate analogies, to identify appropriate episodes that anticipate the behavior of the system about which predictions are being made. In this connection, we should recall Aristotle’s statement that metaphor, or analogy, requires the difficult act of perceiving similarity in the seemingly dissimilar. Even with analogy, we should realize that we are looking through a glass, darkly.

In the following essay, I draw my analogies from case histories that reveal the problematic nature of predictions about technological change, that demonstrate the role of human agency, and that also suggest the deterministic forces that the Internet is likely to generate a sociotechnical revolution in much the same way that electric power and the internal combustion engine first brought a sociotechnical revolution and then initiated a sociotechnical revolution generally known as the Second Industrial Revolution (1870–1940). The move from a technical to a sociotechnical revolution occurred when system builders coordinated technical organizational systems. The insertion of a new source of energy into an existing sociotechnological system usually requires redesigning many components in the system. For example, the application of electric power in factories substantially altered factory design and labor processes. A new energy source can also become the core of a new sociotechnological system, even of a sociotechnical revolution, as was the case with electric power.

Information, like energy, is omnipresent in the human-built environment. A new form of information, like a new form of energy, is likely to generate cascading effects when introduced into existing sociotechnological systems. The Internet is analogous to electric power because both are means of transmission and distribution—in one case energy and, in the other, information. The potential applications of the new information technology are as numerous as those of electric power and the internal combustion engine. When variously applied by inventors and engineers, digital information is likely to bring a technological revolution in the Internet system. System builders will foster a sociotechnical revolution.
Already there is an anticipation canon. Because of the glittering status of the new-economy corporate world, supporters imagine that technology-enabled education will take on a corporate style. Academic administrators are encouraged to use a Silicon Valley management style: campus-corporate joint ventures, mergers, and acquisitions are in vogue; patent law policy is applied to faculty-generated courses, now called "courseware," entrepreneurial activities are thrust upon the faculty; and college and university presidents are urged to learn from corporate CEOs and reengineer their institutions.

The attraction of the corporate management style in academia today is reminiscent of the widespread envy of the natural sciences—especially physics—among higher education institutions in the 1990s. Even historians tried to transform their art into a quantitative science. Engineering schools became schools of "applied science." The great center of engineering, MIT, characterized itself as an institution polarized—some said paralyzed—around science. Today this era has passed.

We should remember that appealing visions have often proved to be chimerical. In recent decades, the high hopes for atomic energy in the United States were not fulfilled. Cold fusion and superconductivity were short-lived enthusiasms. Because of the glittering status of the new-economy corporate world, supporters imagine that technology-enabled education will take on a corporate style. Academic administrators are encouraged to use a Silicon Valley management style: campus-corporate joint ventures, mergers, and acquisitions are in vogue; patent law policy is applied to faculty-generated courses, now called "courseware," entrepreneurial activities are thrust upon the faculty; and college and university presidents are urged to learn from corporate CEOs and reengineer their institutions.

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Pattern 2: Unanticipated Applications

The history of the internal combustion engine provides a memorable example of unanticipated applications of technical systems. It is highly unlikely that anyone predicted that the internal combustion engine would culminate in the Second Industrial Revolution.

Initially, the internal combustion engine was intended for craftspeople and small manufacturers. Its original inventors did not intend for the engine to be used for transportation systems; others saw this possibility. Even they, however, could not have anticipated the far-reaching consequences of the new engine. In 1885, Gottlieb Daimler, a German engineer, adapted the engine for vehicles by decreasing the weight-to-horsepower ratio, greatly increasing the revolutions per minute, and by substituting liquid petrol for a gaseous fuel. As is often the case with a new artifact, Daimler placed his invention on familiar platforms—bicycles and former horse-drawn carriages.

By 1890, however, the Frenchman Émile Levassor and his partner, René Panhard, were building integrated automobiles according to their system. Vehicle components, such as the engine, transmission, and frame, were designed to function harmoniously as a motorcar. As one historian has noted, "The genius of Levassor lay in assembling these [and other components] in a system which comprised a motorcar, in embryo, as distinct from a horseless carriage." In the hands of Americans such as Henry Ford, the motorcar became the core technology in the automobile production and use system that continues to transform the U.S. landscape.

Other inventors maintained the sequence of unanticipated applications. At about the turn of the century, a German, Ferdinand Graf Zeppelin, used the light engine to provide propulsion for a navigable balloon. Orville and Wilbur Wright adapted the petrol engine to a heavier-than-air craft, an innovative process that culminated in their historic flight of 1903. The Wright brothers anticipated that their aircraft would be used by the military; but they did not foresee the dramatic transformation in military and commercial aviation that would transpire during the twentieth century.

Pattern 2 Analogy: Unanticipated Applications in Technology-Enabled Education

The future of technology-enabled education will involve computer and Internet applications not anticipated by present-day inventors and developers. Predictions of future developments in technology-enabled education are mostly projections of contemporary developments. Richard Larson and Glenn Streilein point out that some putative innovations in technology-enabled education are essentially slight improvements in existing educational practices. For example, distance learning is usually a carryover from traditional classroom teaching. They compare this projection of the past into the future to the early railway coaches, which were simply traditional horse-drawn coaches put on rails. The technology-enabled innovations that may transform education are likely to be radical breakthroughs, inventions bringing a sharp break with past practice.

Creators of ARPANET, the forerunner of the Internet, did not forecast the rapid spread of e-mail. Nor did early predictions about the future of computer networks foresee the Internet. The developers of the World Wide Web did not forecast its tremendous impact on libraries. Failures to envision make a long list.

Awareness that many technology-enabled education innovations cannot now be anticipated should caution enthusiasts not to lock into innovations presently available. Early lock-in will bring the constraints of path dependency, the classic example being the present use of the QWERTY keyboard.

Pattern 3: Independent Inventors

It was not technological determinism, but instead chance, contingency, and confluence, as well as people and values, that shaped the course of the Second Industrial Revolution. Among those bringing change, the independent inventors stand tallest. As we have seen, they presided over critically important internal combustion engine innovations. They also invented and developed...
other large technical systems at the core of the Second Industrial Revolution.

Elmer Ambrose Sperry’s activities offer an example of an independent inventor’s style. Flourishing in the early twentieth century, Sperry was remembered as the American father of complex feedback controls. A gyrocompass, a naval gunfire-control system, a ship stabilizer, an automatic airplane, and an automatic ship pilot are among his major feedback-control devices. Typically, he presided over radical breakthroughs. Sperry avoided working for a company other than one that he founded and controlled. In this way, he maintained his freedom of problem choice. When engaged in the invention and development process, he maintained his freedom of thought, invention, and development process, he

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Independent inventors who will create major technical systems for technology-enabled education may well be research associates working in university-related, computer and Internet research laboratories. Like Sperry, university researchers tend to concentrate where inventive activity is clustering.

They may form a project group of five or six people who will draw up a proposal and seek funds from a government or philanthropic organization. The group will likely be interdisciplinary and entrepreneurial, which means that it, like Sperry, will pursue the innovation process from invention, through development, and into use.

Pattern 4: System Builders

After inventor-entrepreneurs introduced technical systems during the Second Industrial Revolution, system builders presided over the growth of the sociotechnological systems that increasingly structured the industrialized world. Transportation, communication, and energy systems—composed of both technical and organizational components—superimposed grids and networks upon the landscape and shaped where humans live, work, and play. System builders are a special breed of managers who have the holistic ability to coordinate the intricate activities of research laboratories, to solve the personnel and organizational problems that arise as companies grow larger, to raise the funds that are needed for expansion, and to respond to the political problems that often accompany government regulation.

Consulting engineering and management firms provide an example of system building culminating in a sociotechnological system. They proliferated in the electrical supply industry in the 1920s. Electric Bond and Share Company (EBASCO) and Stone & Webster, both consulting engineering and management firms, dominated the field. Their holistic, integrative approach characterizes system building.

Established in 1905 by the General Electric Company, EBASCO controlled a number of electric utility companies and, through them, a number of technical subsystems—namely electric light and power networks, or grids. EBASCO provided financial, management, and engineering construction services for the utility companies. The system builders of EBASCO saw to it that the services related synergistically. EBASCO management recommended the construction that EBASCO engineering carried out and for which EBASCO arranged financing through the sale of stocks or bonds. If the utilities lay in geographical proximity, then EBASCO often physically interconnected them through high-voltage power grids. EBASCO interacted also with electrical engineering departments in engineering colleges, whose faculty and graduate students conducted research or consulted for EBASCO.

Pattern 4 Analogy: System Builders for Technology-Enabled Education

System builders of sociotechnological systems for technology-enabled education may be individuals, groups, or organizations such as the consulting engineers who built regional electric power systems. The common characteristic shared by system builders is a genius for integrating heterogeneous components—physical, human, and organizational—in a goal-oriented system.

A technology-enabled education system may incorporate a research-and-
buildings in technology-enabled education will begin in a college or university setting but will then move into the management of a system that includes a higher education component.

Pattern 5: Research and Development
The manufacturers of electrical, automotive, telecommunication, and similar systems are engaged in the development of new or improved technology that is being sold to colleges and universities, or to industrial clients who want to develop new technology centers staffed by experts to assist in their projects.

The relative freedom of problem choice enjoyed by university researchers and deans of engineering schools permits the introduction of new technology.

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Pattern 7: Participatory Change
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role in the process. To participate positively in the introduction of technology-enabled education, faculty would become technologically literate through participation in instruction sessions organized by the college or university, probably by the library.

Resistance to technology-enabled education, especially among faculty, abounds. Vested interest in the status quo has high momentum, but it can be overcome by leverage from outside the faculty. It may also be overcome by organizing widespread faculty participation in the introduction of technology-enabled education. Individuals and organizations now dominating the system of higher education may not be those who develop and control technology-enabled education in the future. The providers of gas-light did not introduce electric lighting; the telegraphy companies did not take over telephone technology; carriage-maker companies did not prevail in Detroit; and telephone companies did not introduce point-to-point computer network communications. The list of dominant, high-momentum organizations that failed to introduce the next radical breakthrough in their domain is lengthy.

Presiding over breakthroughs in technology-enabled education requires more than a rational projection of present trends. The future holds unanticipated applications of present technical systems and the introduction of entirely new systems. Thus, technological change is usually unpredictable. One sees its future through a glass, darkly. Those who want to further technology-enabled education may have to cast off from their present organizational mooring and launch themselves into a risk-filled environment, heartened by the belief that unforeseen changes lying over the horizon may be more desirable than those changes seen today.

Notes
7. Examples of such research centers in the computer field are the Media Laboratory at MIT and the Institute for Learning Sciences and the Cognitive Arts Associates with Northwestern University.
11. I have developed the concept of technological momentum in several essays, including “Technological Momentum,” in Morris B. Smith and Leo Marx, eds., Does Technology Drive History?: The Doctrine of Technological Determinism (Cambridge: MIT Press, 1994), 125–13.
12. Morry Meyer, a lawyer and former advisor to the governor of Pennsylvania on legal matters, pointed out to me some of the realities of the relationship between legislators and state higher education institutions.
13. Professor Timothy Lunsford of Stanford University, who has pioneered in the use of technology-enabled education, points out that in the old research-and-teaching model, there was a fit between lecturing, research, and publication. But when faculty begin publishing interactive, multi-threaded narratives, for instance, there will be a closer fit between research incentives and teaching in the technology-enabled education mode. Communication from Lunsford to the author, August 10, 2000.

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