Hughes identifies analogies from the past with the tremendous changes being wrought by technological advancements. He maintains that the future of a system as complex as higher education, with its political, social, and economic components, will not be simply technologically determined. Instead, unexpected and unpredictable events driven by people and their values will greatly affect the course of events. Noting that the telegraphy companies did not take over telephone technology, nor did the dominant carriage makers prevail in Detroit, Hughes suggests that the individuals and organizations now dominating higher education are not likely to control technology-enabled education in the future.
A n i n c r e a s i n g n u m b e r of academic and business adminis-
trators associate technology-enabled education with the infor-
mation revolution. They speak enthusiastically of dis-
tance learning and of “edu-tech” firms, and talk increas-
ingly about virtual universities. Individualized active learning is antici-
pated to displace passive learning. Lifelong learning is a common commit-
ment. 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, especially a technology-enabled component. They make confident predictions about the future of higher education based on this expectation.

History, however, advises caution, even skepticism. In the novel Waterland, Graham Swift wrote,

History is that impossible thing: the attempt to give an account, with incomplete knowledge, of actions themselves undertaken with incomplete knowledge. . . . Yes, yes, the past gets in the way; it trips us up, bogs us down; it complicates, makes difficult. But to ignore this is folly, because, above all, what history teaches us is to avoid illusion and make-believe, to lay aside dreams, moonshine, cure-alls, wonder-workings, pie-in-the-sky—to be realistic.¹

Future changes in higher education will involve actions based on incomplete knowledge. Those making predictions about the future of higher education are doing so with incomplete knowledge. As we shall see, history can help those making predictions and those wanting to preside over changes in higher education to be more realistic.

In this essay, I assume there are systems within systems.
Technology-enabled education is nestled within higher education, and higher education is nestled within an information revolution that has the Internet at its core. The mix of systems is rapidly changing over time. Changes in systems as complex as these are sociotechnical, not simply technical. Technical systems consist of hardware and software components. Sociotechnological systems have organizational components as well as hardware and software components. Sociotechnical systems are more complex and messy than technical systems, hence their future is more difficult to anticipate. Realistic skepticism about prediction is imperative.

My overarching thesis is that we should reject predictions based on the assumption that technology-enabled education is an isolated technical system. It is a nested, sociotechnological system. We should not simply extrapolate from the present state of technology-enabled education into the future. The contexts that shape a system change over time, so we should not assume that an expanding system would continue to expand at its present rate. Instead of simple linear extrapolation, we should use historical analogies to peer into the future of sociotechnological systems.

By examining the history of sociotechnological systems that appear to be analogous to the system of technology-enabled education, we can suggest by analogy likely futures of technology-enabled education. My task as a historian is to choose these analogies. 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.

IS THE INFORMATION REVOLUTION CHANGING EVERYTHING?

Before discussing these patterns of change, I will examine the argument that the information revolution, specifically the Internet, will “change everything,” including higher education. This seems likely if the Internet system fosters a sociotechnical revolution comparable to industrial revolutions of the past. These industrial revolutions changed everything, including education.

The Internet will likely generate a sociotechnical revolution in much the same way that electric power and the internal combustion engine first brought about a technical revolution and then a sociotechnical one generally known as the Second Industrial Revolution (1870–1940). The move from a technical to a sociotechnical revolution occurred when system builders coordinated technical and organizational systems.

The insertion of a new source of energy into an existing sociotechnological system usually requires redesigning many components in the system. The application of electric power in factories substantially altered factory layout 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 also likely to generate cascading effects when introduced into existing systems. The Internet is analogous to electric power because both are means of transmission and distri-
bution, in one case of energy and in the other, of information. The potential applications of the new information technology are as numerous as those of electric power and the internal combustion engine. When applied by inventors and engineers, digital information will likely lead to a technical revolution. Later, system builders will foster a sociotechnical revolution.

EVERYTHING CHANGES, BUT NOT AS ANTICIPATED

It is reasonable to predict that the Internet is changing everything in a way similar to the industrial revolutions of the past. Yet, history suggests that everything will change in unanticipated ways.

In the 1920s, for example, a number of social scientists, public intellectuals, and industrialists believed that they were experiencing a sociotechnological revolution. They labeled it a Second Industrial Revolution involving electricity, automobiles, telephones, and radio, as well as organizational, social, political, and demographic changes.

While correctly anticipating momentous changes, they frequently erred in anticipating the nature of those changes. As we shall discover, although they thought their predictions were value-free, they unwittingly imposed their values upon the technological future. They believed that the new technical systems would predictably drive social changes; they knowingly or unconsciously embraced technological determinism.

The predictions of Lewis Mumford, an informed and wise public intellectual, offer an excellent indication of the difficulty of forecasting large-scale sociotechnical change. In two early books he developed a concept of 19th century New England regionalism that he persistently advocated. He believed the Second Industrial Revolution would bring a new, ideal regionalism.
Mumford portrayed his ideal 20th century region as having moderately sized, culture-cultivating cities, comparable to the historic New England towns, surrounded by a sustaining food-growing countryside pocketed with small industrial villages where industrial workers also farm. A system of roads links the population centers. Industry draws upon waterpower sources and from electricity transmission lines. Thermal power plants situated at coal-mining sites are major suppliers of energy. Coal is not burned, but distilled to draw off valuable byproducts. The residual coke is fired. Transmission lines hundreds of miles in length distribute energy throughout the region. Industry is no longer limited to the lowlands where the coal-carrying railroad networks spread. It moves to the highlands where hydroelectric plants flourish. People living on the countryside have the radio to enrich their lives, the telephone to involve them in social networks, and the automobile to provide mobility. Electrical motors and internal combustion engines free farmers from the heavy labor of their past.

Although Mumford correctly recognized that the country had been experiencing an industrial revolution, he incorrectly believed that it would inexorably bring the regionalism he so ardently desired. He repeated the mistake of many technological change enthusiasts and forecasters: he envisioned a scenario involving a logical sequence of social, political, and cultural changes following in the wake of technological change. Although not acknowledged, he embraced value-free technological determinism. In fact, his values shaped his predictions.

Mumford failed to recognize that technology is malleable, shaped by values. Young Mumford was a technological determinist, albeit a soft one. He ignored the aspirations and predictions of those with a different agenda for the new technology. Some of them had a personal stake in maintaining the urban status quo and opposing Mumford’s regionalism. While he foresaw a network of roads linking small cities and rural
communities, others laid out highways that moved traffic into large cities. Foes of regionalism supported construction of subways and streets allowing more commuters to reach and move within the large cities. High-rise buildings accommodated more professionals and workers in inner cities. Instead of mine-mouth power plants, urban power plants receiving coal by rail from distant mines continued to function. He anticipated that electric power, automobiles, radio, and telephone would make rural living so attractive that young people would remain on the farms, but they fled the countryside. Mumford envisioned small garden cities surrounded by greenbelts, while suburbia attached itself to the large cities.

**ANALOGY: VISIONS AND VESTED INTERESTS**

University administrators and faculty envisage a technology-enabled education that reinforces their visions and vested interests. Like Mumford, they tend toward self-serving technological determinism. They imagine that computers and the Internet inexorably bring change. Their optimism sustains their enthusiastic commitment to technology-enabled education.

There is already an anticipation canon: because of the glittering status of the new economy corporate world, supporters of technology-enabled education imagine it taking on a corporate style. Academic administrators are encouraged to use a Silicon Valley management style: university-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 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 natural science envy (espe-
cially physics) that was widespread in universities in the 1950s. 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. This era has passed.

We should realistically 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.

**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, inventors of the internal combustion engine intended it for craftspeople and small manufacturers, not for transportation systems. Others saw this possibility. However, even they could not have anticipated the far-reaching consequences of the new engine. In 1883, Gottlieb Daimler, a German engineer, adapted the engine for vehicles by decreasing the weight-to-horsepower ratio, greatly increasing the revolutions per minute, and substituting liquid petrol for a gaseous fuel.4 As is often the case with a new artifact, Daimler placed his invention on familiar platforms — bicycles and formerly horse-drawn carriages.

By 1891 a Frenchman, Emile Lavassor, and his partner, René Panhard, were building integrated automobiles according to their *système*. Vehicle components, such as the engine,
transmission, and frame, were designed to function harmoniously as a motorcar. “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 focus of the automobile production and use system that continues to transform the American landscape.

Other inventors maintained the sequence of unanticipated applications. Around 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 the 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 could not have foreseen the dramatic transformation in military and commercial aviation that would transpire within the century.

**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 Strehle suggest that some putative innovations in technology-enabled education are essentially slight improvements in existing educational practices. For example, distance learning has evolved from traditional classroom teaching. They compare this projection of the past into the future with early railway coaches that were simply traditional horse-drawn
coaches put on rails. The technology-enabled innovations that may transform education will probably be radical breakthrough inventions, bringing sharp changes to past practice.

The 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 upon 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.

**SYSTEM BUILDERS**

After inventor entrepreneurs introduced technical systems during the Second Industrial Revolution, system builders presided over the growth of sociotechnical 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 an ability to coordinate the inventive activities of research laboratories, solve the personnel and organizational problems arising as companies grow large, raise the funds needed for expansion, and respond to the political problems that often accompany government regulation.

Engineering and management consulting firms provide an example of system building culminating in a sociotechnical
system. They proliferated in the electrical supply industry in
the 1920s. Electric Bond and Share Company (EBASCO) and
Stone & Webster, both engineering and management consult-
ing firms, dominated the field. Their holistic, integrative ap-
proach 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 elec-
tric light and power networks, or grids.\(^7\) EBASCO provided fi-
nancial, management, and engineering construction services
for the utility companies. The system builders of EBASCO saw
to it that the services related synergistically. EBASCO man-
agement recommended construction that EBASCO engineer-
ing carried out and for which EBASCO arranged financing
through the sale of bonds or issue of stock. If the utilities lay
in geographical proximity, EBASCO often physically intercon-
nected them through high-voltage power grids. EBASCO in-
teracted also with electrical engineering departments in engi-
neering colleges, whose faculty and graduate students
conducted research or consulted for EBASCO.

ANALOGY: SYSTEM BUILDERS FOR
TECHNOLOGY-ENABLED EDUCATION

System builders of sociotechnical systems for technology-en-
abled education may be individuals, groups, or organizations
such as the consulting engineers who built regional electric
power systems. The common characteristic shared by sys-
tems builders is a genius for integrating heterogeneous com-
ponents (physical, human, and organizational) in a goal-
oriented system.

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

The heads of EBASCO during the interwar period began as engineers and moved into management of a heterogeneous system. Conceivably the system builders in technology-enabled education will begin in a university setting, then move on into management of a system centered around a university component.

**MOMENTUM: RESISTANCE TO CHANGE**

People and their values shape technology. They can effectively delay or even prevent technological change. Massive sociotechnological systems, such as educational systems, have characteristics analogous to the physical inertia of motion. Involving a mass of human, technical, organizational, and attitudinal components, higher education systems tend to maintain steady growth and direction. The extremely large investment of physical and human resources in education averts disruptive changes that threaten to de-skill professors and administrators and to make existing physical plant and equipment obsolete.

How has resistance to technological change been overcome in the past? After World War II, U.S. Air Force officers experienced in and enthusiastic about flying aircraft resisted the introduction of intercontinental ballistic missiles (ICBMs). They raised doubts about the ability of missiles to carry heavy atomic warheads to targets in the Soviet Union. They questioned the possibility of designing a missile guidance system
that would insure reasonable missile accuracy. And they argued that materials for a heat shield that would protect the warhead during reentry into the atmosphere could not be developed.

Advocates of ballistic missiles within and outside the Air Force countered that adequately funded research and development could bring early solutions to the problems. They contended that conservative Air Force policy makers customarily exaggerated the severity of problems, then failed to allocate funds to solve them.

As is often the case in the history of technology and culture, authorities outside a high-momentum system provided the leverage for change. In this case, civilians highly placed in the Defense Department, citing a presumed threat from Soviet missiles, threatened to turn development of an ICBM over to a civilian agency. The Air Force hierarchy capitulated.8

**ANALOGY: LEVERAGE FOR CHANGE**

In the ICBM case authorities from outside the system instituted change. In the case of universities, those with power outside the system may overcome resistance to technology-enabled education. Who might they be?

In the case of public universities, state legislatures have, in principle, the power to bring about changes in the system of higher education. They rarely exercise that power, except in financial matters. If technology-enabled education were defined as a financial matter, and if a committee or commission were established to investigate it, then the legislature might ask to appoint several members of the group.9 Boards of overseers have similar financial leverage in private universities. Coming from the private and philanthropic sectors, they have a point of view often differing from that of academe. Philan-
thropic and governmental funding agencies could cultivate technology-enabled education by soliciting and supporting funding in areas of change.

**PARTICIPATORY CHANGE**

A participatory approach may help overcome resistance to disruptive technology for cultural reasons. A case in point is the one taken in the 1980s by advocates of the Boston Central Artery and Tunnel, a technologically complex highway project now underway. It will place a downtown elevated highway underground and offer a new harbor tunnel to Logan Airport and a new bridge across the Charles River.

In the 1980s, activists offered effective resistance to highway construction in Boston and elsewhere in the United States. Highway engineers had a reputation for thrusting highways through cities and across the countryside without taking into consideration their disruptive effects upon communities and people.

The advocates of the Boston Central Artery and Tunnel countered this resistance in part by promising that the highway system would be subject to public scrutiny and hearings during preliminary and final design. The Massachusetts Highway Department responded to the comments of groups and individuals appearing at the hearings or participating through written comment.

**ANALOGY: FACULTY PARTICIPATION IN TECHNOLOGY-ENABLED EDUCATION**

Because relatively few faculty can perform (or are willing to take the time to perform) the complex tasks associated with
technology-enabled education (especially the use of media and the interactive mode), leading universities have established technology centers staffed by experts. Professors can simply turn over distance learning delivery to on-campus experts.¹⁰

The drawback of this approach is that faculty loses control over essential teaching and learning experiences. Often the experts are driven by technical and financial considerations, and tend to overlook other values dear to the faculty.

To counter these negative effects, university administrators and departmental chairs can encourage, even require, faculty participation in the introduction of technology-enabled education. A technology expert would not simply take over the technology function, but would work cooperatively with faculty members. Faculty would play a hands-on role in the process. To positively participate in the introduction of technology-enabled education, faculty would become technologically literate through instruction sessions organized by the university.

**INFORMATION-DRIVEN CHANGE**

Technological change has been as rapid in the past as it is today, but only during those periods of transformation that we have labeled industrial revolutions. These revolutions involved basic alterations in the way energy was generated and transmitted. We are in such a period of transformation today because the effects of basic changes in the way information is generated and transmitted also cascade through social structures.

Inventors, engineers, and scientists enjoying freedom of problem choice have shown themselves adept in directing radical technological change during the information revolution. They flourish in research centers associated with universities, rather than in discipline-bound academic departments.
System builders are needed to create and oversee the socio-technical systems that contain and sustain technological change. A technology-enabled education system in the future may incorporate a university department, a for-profit software developer, a venture capital firm, a consulting group of experts in technology-enabled education, and network hardware and software facilities.

Resistance to technology-enabled education abounds, especially among faculty. Vested interest in the status quo has high momentum, but it can be overcome by leverage from outside. It also might 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 the ones who develop and control future technology-enabled education. The providers of gaslight did not introduce electric lighting; the telegraphy companies did not take over telephone technology; carriage making companies did not prevail in Detroit; and telephone companies did not introduce point-to-point computer network communications.

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, some of them sociotechnical. Thus, technological change is usually unpredictable. One sees its future through a glass darkly. Those who wish to further technology-enabled education may have to cast off from their pre-
THROUGH A GLASS DARKLY

sent organizational mooring and launch themselves into a risk-filled environment, heartened by the belief that unforeseen changes over the horizon may be more desirable than those they see today.

NOTES


8. I have developed the concept of technological momentum in several essays, including “Technological Momentum,” *Does Technology Drive History*, Merritt Roe Smith and Leo Marx, eds. (Cambridge: MIT Press, 1994), 101–13.

9. Morey Meyer, a lawyer and former adviser to the governor of Pennsylvania on legal matters, pointed out to me some of the reali-
ties of the legislature’s relationship to state universities. Communication from Meyer to author, September 2000.

10. Professor Timothy Lenoir of Stanford University, who has pioneered in the use of technology-enabled education, points out that in the old research-teaching model there was a fit between lecturing, research, and publication. When faculty begins publishing interactive, multithreaded narratives (for instance), there will be a closer fit between research incentives and teaching in the technology-enabled education mode. Communication from Lenoir to the author, August 30, 2000.

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