
CAN THERE BE A RENAISSANCE OF THE PH.D.?

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Profound social and technological changes during the last three decades have created a new context for Ph.D. education. This essay surveys and critiques the current state of the Ph.D. and explores how a restructuring of the Ph.D. can make the degree more relevant for meeting the challenges of our time.

Technological revolutions create an objective need for social and political innovations. They create a need also for identifying the areas in which new institutions are needed and old ones are becoming obsolete.

Peter F. Drucker in *The Ecological Vision*

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THE IMPLICATIONS of this concrete observation made by Peter Drucker (1965) have yet to be fully appreciated, much less acted upon over the last three and a half decades. During this time period, American society has been transformed by the advance of science and technology, especially digital technology (including software and high-speed networks), that has revolutionized the way humans use information and communicate locally and globally. These dramatic innovations in human communication have occurred during a period that has

also witnessed significant geopolitical and economic realignments. The collapse of the Soviet Union, the formation of a European Union, the signing and implementation of NAFTA, China's engagement with the world economy, and the rise of radical Islam have all dramatically reshaped world affairs. Moreover, the planet faces significant environmental challenges. Global warming, the depletion of fisheries from the world's great oceans, deforestation, erosion, and concentrations of highly toxic and long-lasting pollutants will pose near insuperable obstacles for humans in the decades ahead. Taken together, these events and circumstances identify our time as more than a period of rapid change. It is, instead, a revolutionary period in human history in which the ascent of science and technology and unprecedented social and environmental change have outstripped humans' capacity to respond to their natural and social environments effectively and consistently. These changes have placed our society and our planet on the edge of jeopardy.

It is in this context that I examine the Doctor of Philosophy degree and other aspects of graduate education. Significant changes have occurred in Ph.D. education during the last thirty-five years. Many of these changes are linked to advances in information technology and to the revolutionary new social realities previously mentioned. I survey and critique the current state of the Ph.D. in this essay. I then explore how a restructuring of the Ph.D. can make the degree more relevant for meeting the challenges of our time.

Implicit in my discussion of the Ph.D. is the premise that the research university, the institutional home of Ph.D. education, has not responded in a coherent fashion to the massive social, environmental, and technological changes that have taken place over the last three decades. As a result, Ph.D. education is in danger of becoming a vehicle that compounds social disorder by preparing thought and action leaders who are fundamentally unsuited to meet the new realities of our time.

The “new realities”¹ are challenging the stability of our society and all of its organizations. Their influences on society are every bit as great as those experienced during the Industrial Revolution, a period that also witnessed far-reaching transformations in the structure of work, human communication, global ecosystems, social relations, and educational, economic, and political organizations (Benson and Lloyd, 1983; Horrell and Humphries, 1992; Stearns and Walkowitz, 1974; Timmons, 1986). It, too, was a revolution that placed Western society and our planet on the edge of jeopardy. But in the wake of industrialization in America, dramatic institutional innovations served to ameliorate the social, economic, and political (but not environmental) effects of revolutionary change.

Institutional innovations, that is, formal institutional responses to nineteenth-century industrialization, remain an essential part of America’s daily life. The land-grant university that celebrates advancement of the “mechanical arts,” the U.S. corporation that grew from assembly line labor, a banking system that permits credit and investment, and an economic and political system that segregates the activities of business and commerce from those of the individual stand as testament to the social and political innovations that fundamentally altered our society.

America’s institutions have not been moribund during the last thirty years; in fact, they have responded to the changing social and technological landscape. For example, information technology (hardware, software, and networks) has been incorporated into the fabric of work and play. It is not possible to

¹ I’m not sure exactly what to call the revolution I describe. Some have dubbed it the “information revolution.” In my view, this term captures a portion of what has occurred, but it ignores the dramatic global realignments that have taken place and does not incorporate the important environmental challenges, such as global warming, that currently face the planet. Consequently, I adopt the term used by Peter Drucker in much of his writing, “the new realities.”

do business today in any meaningful way without relying on the advances in data analysis and communication that have accompanied the emergence of these exciting new technologies.

Globally, there is indeed a new world order (or should I say disorder?). International political and economic realignments are taking place. Powerful economies have formed in Europe, Latin America, and Asia that influence the balance of power in the world. At home, America's prodigious research and development efforts have been refocused from nuclear deterrence to biomedical science and, more recently, to the spate of issues raised by the threat of global terrorism.

Yet the form and structure of America's governmental, educational, and business institutions have barely begun to adapt to these new realities. Organizationally, our institutions are still following patterns that were shaped by forces of the early twentieth century. While certain practices within organizations are adapting to changing times (e.g., use of the Internet as a delivery mechanism for all kinds of goods and services, including education), such changes have been unstructured and poorly integrated. As a result, they have primarily affected the periphery, not the core, of these institutions.

This kind of organizational response has been termed "patching" by Eisenhardt and Brown (2001). For the last three decades, the research university has been practicing an expedient strategy of patching as it has responded to contingencies of budget, changes in the federal research agenda, enrollment challenges, and curricular modifications designed to explore new demographic, political, and social realities. We may now find "smart" classrooms, Web-based instructional platforms, wireless environments, distance education, and online degrees in the research university, but these radical technical innovations have been incorporated into the existing structure and organization of the traditional university. Given our new realities, I believe it is now time for deeper, more substantial innovation in higher education.

Historically, America's research universities have been a rich source of innovation and social change. They have led the way, especially in science and technology, during the last 50 years. Most of the technological advances of these past decades ultimately trace their origin to a university laboratory. The success of the science and engineering fields, in fact, has created a kind of technocracy inside the research university (Upham, 2002). The foundation of this technocracy is an ever-deepening specialization by practitioners within the disciplines.

While specialization is clearly the driving force behind the stunning technical advances of the past three decades, it also has the effect of creating barriers to communication, or "silos" within the university. Initially, these silos formed around academic disciplines—anthropologists and sociologists speak very different disciplinary "languages," even though the focus of their scholarship is on society and culture. The same barriers can be found between chemists and biologists or economists and political scientists.

Today, however, the ethos of aggressive specialization within the research university is creating *intradisciplinary* silos. That is, silos are forming that impede communication between specialists within the *same* field. Witness the schism that has occurred in the field of biology between cell biologists, molecular biologists, and those who study ecology and evolution. Teachers and researchers within each subfield are becoming more and more isolated from each other by the requirements of escalating specialization, and this process of segregation is occurring across the disciplines.

It has become increasingly clear that silos of technocracy built on unbridled specialization are ill suited for preparing Ph.D. students to meet the multifarious social and scientific challenges that confront us. America's research universities need to move beyond (but not abandon) the triumph of specialization. To begin, they must vigorously counteract escalating specialization by refocusing requirements for the Ph.D. degree. After all, it is America's Ph.D. programs that prepare each generation's scholars and professionals for intellectual, techni-

cal, and social leadership. The new realities are demanding that we give our Ph.D.'s a different basis for acting in tomorrow's global society.

PH.D. EDUCATION: WHERE ARE WE?

John Seely Brown and Paul Duguid (1995) have provided a very provocative answer to the question: "What do America's research universities do?" Brown and Duguid suggest that the core competency of the research university is not the awarding of degrees or even the transfer of knowledge. Rather they argue that the core competency of the research university is in developing knowledge within "intricate and robust networks and communities." They go on to describe the communities they envision as "enduring interpersonal relations that form around shared practices." Brown and Duguid believe that "people come to share the same community by sharing the same tasks, obligations, and goals."

Nowhere is the Brown-Duguid notion of community more evident than in the structure and practice of contemporary Ph.D. education. The building blocks of doctoral education are communities: faculties assembled by discipline, student cohorts, and individual students working with faculty committees. Within and between each of these groupings, enduring bonds are created around the learning and discovery process. Moreover, these communities have structure and duration; that is, such communities have unique histories built around tasks, obligations, and goals. Brown and Duguid see academic disciplines as communities of "concept users" that are bound together by shared practices and institutional arrangements. Following Lave and Wenger (1991), they also argue that all learning involves "enculturation in communities" that produces "communities of practice."

Contemporary Ph.D. education is built upon a series of cumulative pedagogical steps. At the intake or master's level, the

breadth of knowledge in a field is explored.² Following completion of the master's, Ph.D. education focuses on *depth, specialization, and original research* in a subject area. Doctoral students identify a body of knowledge, study it systematically, and then demonstrate mastery of that knowledge to professors and peers in both oral and written forms. At the Ph.D. level, mastery is intended to lead the student to the creative use of knowledge and, ultimately, to independent, original discovery. This latter phase of doctoral study is devoted to research, analysis of data, and writing of the dissertation.³

A central feature of Ph.D. education is the close working relationship that graduate students develop with the faculty who teach them. Many have referred to the structure of Ph.D. education as an apprenticeship in which the “apprentice” student works with “master” faculty members. This metaphor accurately captures the traditional model of Ph.D. education in which students are moved through their programs of study after demonstrating mastery via a sequence of courses, exams, proposals, essays, research experiences, and written and oral defenses of their knowledge base. The capstone of the apprenticeship is the completion of the Ph.D. dissertation and its public, oral defense. In many cases, the bonds created between and among students and faculty during the Ph.D. apprenticeship evolve into lifelong professional relationships. Such longitudinal relationships extend and reify Brown and Duguid's notion of communities of practice.

²In professional master's programs, in addition to breadth, the student is expected to gain a working knowledge of practice in the field. Master's education in U.S. universities is currently the fastest growing sector of American graduate education.

³Professional doctoral programs follow this general outline but are less concerned with discovery and basic research and rarely have dissertation requirements. Rather, they are structured to develop diagnostic skills and technical competencies at the highest level. Often times, professional doctoral programs include intensive internships in which students gain their professional standing in the field.

Today, there are 535 doctoral degree-granting institutions in the U.S.⁴ Nearly all that confer the Ph.D. follow the general outline I have just described. But Ph.D. education is not static. It has changed dramatically during the last 30 years, as Ph.D. programs have sought to adapt to the revolutionary changes that have swept society. For example, all Ph.D. candidates were once expected to acquire a reading knowledge of the principal languages in which research in the field was published. Generally, this requirement meant that a student would need to learn at least two languages in addition to English during his or her course of study. Two forces have acted to modify this requirement. First, increasing specialization at the Ph.D. level has meant that more and more time be devoted to the process of original research and discovery. In the context of specialization, language requirements are viewed as diluting the research foundations of the Ph.D. degree.

Second, the emergence of English as a global “lingua franca” during the post-World War II period has made English the language of scholarship. Hence, the Ph.D. language requirement gave way to one foreign language validated by examination and then collapsed completely to a “tools” requirement in the 1980s. In many Ph.D. programs today, appropriate tools include demonstrating competence in experimental statistics, computer languages, database construction and use, or even Web page design.

Similarly, full-time enrollment and residency requirements were once mainstays of Ph.D. education. It was simply not possible to pursue the Ph.D. on a part-time basis. Ph.D. programs were constructed to make sure that course offerings and exams conformed to the full-time schedule. The residency requirement was intended to ensure that a Ph.D. student was on campus for

⁴There are also 1,499 master’s degree-granting colleges and universities. Digest of Education Statistics, National Center for Education Statistics, Washington, D.C., 2001 (<http://nces.ed.gov/pubs2001/digest/ch3.html#3>).

one entire year, working directly with professors and peers, engaging actively in departmental affairs (especially brown-bag lunch discussions, book groups, and afternoon colloquiums), and making use of the principal academic resources of the campus (libraries, specialized laboratories, and research facilities).

The changing demography of the country, a need for lifelong learning stimulated by the new knowledge economy, and advances in information technology have rendered both the full-time enrollment and the residency requirements obsolete. Today, many Ph.D. students pursue their programs of study on a part-time basis. Many, in fact, are never full-time students. Distance learning and online degrees now make it possible for Ph.D. students at some universities to earn degrees without ever having to set foot on campus. These students participate virtually in the academic culture of their program using the Internet and e-mail to interact with professors and peers.

The duration of graduate instruction used to be measured by the “Carnegie unit,” a period based on the number of hours a student had studied discrete subjects.⁵ Generally, master’s degrees required 36 semester Carnegie units and Ph.D. degrees a minimum of 72. Graduate credit was never to be earned faster than one Carnegie unit per week. Thus, the maximum number of units a graduate student could earn over the course of a 15-week semester was 15.

Today, the Carnegie unit has all but disappeared from the lexicon of higher education. Driven by demands for greater

⁵ “The Carnegie unit is a crude measure of exposure to teaching and does not evaluate either the quality of presentation by the teacher or the quality of learning by the student.” A Carnegie unit at the graduate level generally equates to a total of 45 semester hours of instruction in one subject—meeting 3 times a week, for 60 minutes, for 15 weeks each semester. See N. Jantzie, “Distance Learning and the End of the Carnegie Unit” (www.ucalgary.ca/~gnjantzi/distance_learning_and_the_end_of.htm).

efficiency in the delivery of instruction, most universities have adopted more flexible understandings of the class schedule. “Seat time” is no longer viewed as a reliable indicator of instructional quality. Indeed, a learner-centered model of education has taken hold that has introduced self-paced learning and changed the role of the professor from “sage on the stage” to “guide on the side” (Frick, 1997). The learner-centered model has gained support as the economics of higher education have become more problematic and enrollment demands from the baby-boom echo create capacity problems in universities.

In addition, many Ph.D. students also work full time outside of the university. Such students used to be referred to as “nontraditional.” Today, however, they are far more common. The rise in enrollment of nontraditional students has led to the modularization of instruction. That is, many graduate courses are now offered in short bursts of instruction that may encompass intensive effort over a period of two or three days to two or three weeks. The predominance of working professionals pursuing the Ph.D. has made this kind of scheduling routine in many programs.

In an increasing number of cases, Ph.D. instruction is also offered “on demand” in asynchronous formats. In such programs, students can access instructional materials at a distance without regard to class schedules. Generally, these students work alone and are not part of a face-to-face community of practice. Some see this kind of “any time-any place” Internet-mediated instruction as a model of the future. Others decry its introduction, seeing it as a utilitarian assault on Ph.D. education’s community-based structure.

Finally, the *sine qua non* of Ph.D. education is the demonstration of original, independent scholarship by the doctoral candidate. Generally, the Ph.D. dissertation not only reflects the student’s mastery of a subject but also is the vehicle for presenting the student’s original contribution to knowledge. The hallmark of such studies is the advancement of new understanding, the presentation of genuinely new perspectives

or theories, and/or the presentation of a discovery, breakthrough, or synthesis in a narrow area of inquiry.

Today, the dissertation is the first important step a practitioner makes in a career of ever-increasing specialization in a subject area. Specialization, the process of exploring narrower and narrower aspects of a question or body of knowledge, begins within the Ph.D. committee—the first “community of practice” the student knows. It is the job of the Ph.D. committee that oversees the dissertation to judge the accuracy, completeness, reliability, and character of the work. But because of specialization, the student is generally the most knowledgeable person on the subject in the room during an oral defense. The natural outcome of such progressive specialization in a field is the creation of intradisciplinary silos.

Today, some Ph.D. dissertations do not demonstrate independent scholarship and do not make an original contribution to knowledge. Indeed, the predominance of the reportorial “case study” in fields such as education and many of the social sciences has turned the dissertation into a simple journalistic exercise. Similarly, pressure has been mounting in the sciences for many years to allow students to collate published research articles that have appeared in scholarly journals and to submit them in lieu of the dissertation. Often times, articles included in such collations have multiple authors, meaning that the student’s original contribution to knowledge may be difficult to define and assess. This circumstance arises as much from the way scientific research is conducted today in teams as it does from the increased specialization that drives each investigator into narrower and narrower niches.

ADAPTIVE CHANGE?

The changes I describe show that practice in Ph.D. education is evolving. Taken together, the modifications have dramatically altered the process of earning a Ph.D. Both the number and the characteristics of people who earn the degree have changed. Today, about 43,000 Ph.D.’s are conferred annually in all fields in

the United States, significantly more than in 1956 (the first year national statistics were compiled), when only 8,517 doctorates were awarded.⁶ Major increases in Ph.D. production occurred during the 1960s in response to Sputnik I and the Cold War challenges. But even in 1967, only 20,403 Ph.D.'s were conferred. Thus, we have witnessed a doubling of Ph.D. conferrals during the last 30 years.

When it comes to Ph.D. education, I believe that more is better. After all, how many smart, well-educated problem solvers does the country (and the world) need? Certainly, the answer to this question shall always be more than we can produce. At the same time, I worry that the kind of *ad hoc* and opportunistic changes made to the Ph.D. have created a hybrid degree that is no longer providing a format for educating people who can solve the pressing problems of our time.

Several notable efforts to study the Ph.D. are currently underway.⁷ All are driven by the perception that the Ph.D. has become unresponsive to society's needs. These studies have raised concerns about the excessive length of time students spend in Ph.D. programs (the national average for all fields is about seven years), students' lack of preparation for teaching,

⁶ www.nsf.gov/sbe/srs/sengdr/summ97/start.htm. See Data Tables, Table 1.

⁷ www.woodrow.org/responsivephd. The Woodrow Wilson National Fellowship Foundation Web site lists the agenda, initiative, leadership, and activities of the Responsive Ph.D. initiative. www.grad.washington.edu/envision. The University of Washington's Re-envisioning the Ph.D. project examines how the Ph.D. can be re-envisioned to meet the needs of society in the 21st century. www.norc.uchicago.edu/issues/docdata.htm. The National Organization for Research at the University of Chicago (NORC) is engaged in research on Career Outcomes for Doctorate Recipients. survey.nagps.org. The National Association of Graduate-Professional Students (NAGPS) surveyed more than 32,000 students and recent Ph.D.'s to learn their assessment of educational practices and student satisfaction.

faculty disinterest in mentoring Ph.D. students, employment prospects for Ph.D.'s, and communication barriers arising from progressive specialization.

These issues are relevant to the present discussion, but we need to press deeper into the actual foundations of Ph.D. education. The current conceptual framework allows research universities to produce highly-educated specialists. No system of education has been more successful in this regard. But the new realities call for more than technocrats. Ph.D.'s must also be educated to understand that their specialized knowledge fits within larger frameworks of knowing and understanding. Ph.D.'s must be able to explore the technical as well as the social consequences of research and discovery. They must see the cultural and ethical context of their work and bring to their disciplines a global perspective. Regrettably, we are currently far from realizing this ideal.

TOWARD A NEW CLERISY IN PH.D. EDUCATION

Because the cornerstone of Ph.D. education is the community of practice, meaningful reconstitution of the degree must build from this basic premise. Students working with each other and with graduate faculty must remain the building blocks of Ph.D. education. Thus, the first order of business within the research university is to revivify the principles by which such communities are formed. Basic to this task is to clarify and strengthen the role and purpose of the Ph.D. committee. Importantly, we must elevate the expectations of performance for this vital community of practice. I suggest such expectations be fashioned around five essential elements:

Appropriate Specialization

As noted above, technical specialization should remain a cornerstone of the Ph.D., but it must be balanced against other important objectives. I will never forget my surprise as a new graduate dean many years ago to discover that the Ph.D. program in chemistry at my university had no required

coursework. Instead, students began in the laboratory the first day following the pathways of ever-deepening specialization. When I inquired why this practice was being followed, the terse reply from a senior chemist in the department was that, "There was nothing else to learn from coursework." Of course, what he meant was that incoming graduate students already had a basic understanding of the composition, structure, properties, and reactions of matter. Anything else would have to be learned through experimentation.

This perspective is appropriate for a technocracy. It is not conducive, however, for preparing specialists who can situate their knowledge in the broader world. Today, all Ph.D. students should be required to contextualize their knowledge and understandings in light of findings and perspectives from the broader field. Moreover, they should see their discipline in relation to other related bodies of knowledge, and they should be able to communicate not just with specialists in their own field but with specialists from a variety of fields who study related phenomena. In other words, specialization must be balanced against the need to place specialized knowledge in a broader, *transdisciplinary* context.

Context

Transdisciplinarity, the notion that a scholar pursues ideas wherever they may lead, is a touchstone of the next society. The most vexing and difficult problems of our time are not defined by disciplinary boundaries. Rather, they are by definition, complex, multidimensional, nonlinear, and evolving. In the face of such complexity, specialization alone is a weak response. While specialized knowledge is required to solve this class of problems, it is by itself insufficient. Scholars who are able to work across disciplinary boundaries to synthesize and integrate relevant data, information, and knowledge will be the most successful problem solvers of tomorrow.

Where do Ph.D. students acquire such skills? Today, Ph.D. programs leave the development of such skills primarily to

chance, with students who have a generalist's inclination becoming the synthesizers and holistic thinkers of their cohort. A more intentional approach is now required. The Ph.D. committee, the most important community of practice for the student, must take responsibility to make sure that each Ph.D. candidate can situate his or her investigations on a broader intellectual map. As ideas are developed and discussed, it should be clear to all (students and faculty) where a particular line of thinking or investigation fits not just historically in the field but also in relation to the range of current research and application.

Global Literacy

The language requirement may have been eliminated from Ph.D. programs, but there remains a pressing need to have Ph.D. candidates learn about how their field is developing around the world. Our planet is too small to pretend that practitioners at the highest level can remain ignorant of how their field is pursued internationally. Every Ph.D. candidate should learn about the global centers of excellence in the field, should be aware of the leading researchers in the international community, and should be able to access and read important work (even if it is not in English) that impinges on his or her research.

This kind of global literacy and technical cosmopolitanism must be introduced to Ph.D. programs in a conscious and deliberate manner from the beginning of instruction. It needs to become a pedagogical feature of Ph.D. programs that is reflected in the way students pursue dissertation research and conceptualize understanding in their field.

Ethics

Ethical standards of conduct have always been a prominent feature of work in the research university. Respecting individual rights of discovery and authorship, preserving the anonymity of respondents, following protocols for research on animals and human subjects are a few of the many ethical conventions followed carefully by faculty and students. The credibility of

research, teaching, and scholarship is predicated on the trust that arises from adherence to these conventions.

Most graduate students acquire a firm understanding of the ethical principles that guide the conduct of their profession. In fact, most Ph.D. programs do a good job of communicating these values. But these values and practices are quite specific to the world of teaching and research. Today, Ph.D. programs must do more. It is no longer enough to inculcate a limited set of ethical standards that apply narrowly to life inside the research university. Most Ph.D.'s will not work inside a research university. Consequently, all Ph.D. students must have a broader and more encompassing understanding of the ethical standards and expectations of conduct that produce "harmonious, constructive, and mutually beneficial behavior" (Drucker, 1981) in settings where knowledge is exchanged and practice takes place at the highest levels.

America exists in a global society of interdependence. In such a society, "a great many people are unimportant and indeed anonymous by themselves, yet are highly visible and matter as leaders in society" (Drucker, 1981). Doctors of philosophy matter in this context as the principal thought and action leaders of tomorrow. Nothing could be more important than making sure our Ph.D.'s are grounded in an ethical foundation that regards interdependence as an essential feature of our global society.

Social Responsibility

All research has social consequences. The creation of new knowledge, even very small advances in understanding in a field, irrevocably changes the relationship of things and people to each other. Ph.D. programs need to focus more intentionally on this process. It is no longer possible to deliver the results of research to an absent and indifferent world. Today, knowledge drives society, and knowledge is social capital. Ph.D. programs have a special obligation as the principal architects and purveyors of knowl-

edge in society to explore the social consequences of learning. Ph.D. students must become socially aware as they gain erudition.

CONCLUSION

Ph.D. education has served the country well over the last 100 years. Indeed, America's Ph.D. programs are deeply implicated in the nation's scientific and social accomplishments. Any changes to the degree must thus be made in ways that preserve the intimate relationship that Ph.D. education in research universities has with the country's social, political, and economic infrastructure.

Changes made in Ph.D. programs over the last three decades, though unstructured and poorly integrated, have enhanced the role that highly-specialized knowledge plays within the research university and in society at large. These modifications to the degree have also significantly broadened access to Ph.D. education.

Today, however, more is required from both our Ph.D. programs and the individuals who receive the highest earned degree. Ph.D. programs must reconceptualize themselves to enable our country's specialists to become holistic, transdisciplinary thinkers. Such individuals must be able to work at the highest levels in their own specialization, but they must also be able to situate their knowledge and communicate with specialists working in cognate and related disciplines.

I am aware that the modifications I suggest to the Ph.D. have substantial implications for the time it may take a student to earn the degree. This issue is not trivial, but I believe that better preparing our thought and action leaders supercedes concerns about time to degree. It is more important to develop within our Ph.D.'s a capacity for synthesis and holistic thinking along with a global cosmopolitanism, even if it means that fewer people earn the degree. If this kind of renaissance in Ph.D. education can occur, then the most difficult and threatening social and environmental problems of our time can be solved in ways that advance peace and prosperity in America and the world.

REFERENCES

- Benson, I., and Lloyd, J. 1983. *New technology and industrial change: the impact of the Scientific-Technical Revolution on Labour and Industry*. London: Kogan Page.
- Brown, J. S., & Duguid, P. 1995. Universities in the digital age. *Xerox Palo Alto Research Paper*. Xerox Corporation.
- Drucker, P. 1965. The first technological revolution and its lessons (presidential address to the Society for the History of Technology). Reprint, 1993. *The Ecological Vision* 195.
- _____. 1981. Can There Be "Business Ethics?" *The Public Interest*.
- Eisenhardt, K. M., & Brown, S. L. 2001. Patching: rethinking business portfolios in dynamic markets. *Harvard Business Review OnPoint on Strategy in the New Economy* 5874.
- Frick, T. 1997. The most powerful educational system in the world with no one in charge, *Education at a Distance* 14(11). (www.usdla.org/ED_magazine/illuminactive/NOV00_Issue/story05.htm).
- Horrell, S., & Humphries, J. 1992. Old questions, new data, and alternative perspectives: families' living standards in the industrial revolution [1787–1865]. *Journal of Economic History*. 52(4):94.
- Lave, J., & Wenger, E. 1991. *Situated Learning: Legitimate Peripheral Participation*. New York: Cambridge University Press.
- Stearns, P. N., & Walkowitz, D. J. (Eds.). 1974. *Workers in the Industrial Revolution*. New Brunswick, NJ: Transaction.
- Timmons, G. 1986. Science, technology, and education in the industrial revolution. *Endeavour*. 10:85.
- Toulmin, S. 1972. *Human Understanding: The Collective Use and Evolution of Concepts*. Princeton: Princeton University Press.
- Upham, S. 2002. Tracking the endless frontier. *Keynote address to the Society of Integrated Design and Process Science*, 27 June. Pasadena, CA.