The Importance of Liberal Learning for an Increasingly Technological World

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Introduction

During the past several years I have been a frequent visitor to Atlanta to participate in various events concerning the future of higher education hosted by Georgia Tech, Emory University, and the University of Georgia. But this visit provides me with an opportunity to explore a variation on this theme: the nature of liberal learning in a world increasingly driven–if not actually dominated–by technology. Since this symposium celebrates the 10th Anniversary of the Ivan Allen College, an innovative academic college representing the commitment of one of the world's great technology-oriented universities to the liberal arts, my remarks will focus in particular on the importance of the humanities and arts, the social and behavioral sciences, and the values and culture of our civilization for undergraduate education and engineering education in particular.

Interesting enough, two years ago I was invited to give a similar address concerning the future of engineering education at a symposium to celebrate the centennial year of our Department of Chemical Engineering. To prepare for this I went back into the University archives and pulled out sample transcripts to learn more about what engineering education was like a century ago. I was surprised to find it remarkably similar to today's programs. In 1898 we required students to take 130 credit hours of courses in mathematics, physics, and chemistry with a concentration in applied courses in areas such as mechanical, civil, and chemical engineering. In fact, if one swaps yesterday's requirement for surveying and mechanical drawing for today's courses on computers, the two curricula are almost identical. Of course, the actual content of these courses has changed considerably—or so one would hope.

With one major exception, the actual structure of the engineering curriculum has remained roughly the same over the past century. But that exception is an important one. The 1898 curriculum placed far more stress on the importance of a liberal education, with more courses in humanities, arts, and social sciences. In fact, one might even suggest that we have regressed over the past century, overloading our current curriculum with highly specific technical courses at the expense of broader educational opportunities for our students.

Of course, engineering practice today is dramatically different than it was a century ago. Indeed, it is quite different from that of just a few years ago, when most faculty were educated. And this is the theme for my remarks today. This raises an important question: Is the education we provide today for technical professions such as

engineering adequately preparing our students for a world of practice and citizenship that is quite different from the one that we have known?

The context for considering the nature of undergraduate education in general and engineering education in particular is provided by the broader challenges of change characterizing our world and impacting higher education. I believe that the forces of change in higher education are far stronger than most realize. Furthermore, I believe that engineering education will not be exempt from these changes, but may be swept along at the crest of the wave of university change. Put another way, I believe there is little likelihood that the engineering curriculum will continue to preserve its century-old structure in the century—indeed, in the decade—ahead.

A Changing World

Today we are evolving rapidly—decade by decade, even year by year—into a post-industrial, knowledge-based society, a shift in culture and technology as profound as the shift that took place a century ago as an agrarian America evolved into an industrial nation.[1] Industrial production is steadily shifting from material- and labor-intensive products and processes to knowledge-intensive products. A radically new system for creating wealth has evolved that depends upon the creation and application of new knowledge.

In a very real sense, we are entering a new age, an age of knowledge, in which the key strategic resource necessary for prosperity has become knowledge itself, that is, educated people and their ideas.[2] Unlike natural resources such as iron and oil that have driven earlier economic transformations, knowledge is inexhaustible. The more it is used, the more it multiplies and expands. But knowledge is not available to all. It can be absorbed and applied only by the educated mind. Hence as our society becomes ever more knowledge-intensive, it becomes ever more dependent upon those social institutions such as the university that create knowledge, that educate people, and that provide them with knowledge and learning resources throughout their lives.[3]

Our rapid evolution into a knowledge-based society has been driven in part by the emergence of powerful new information technologies such as computers, telecommunications, and high-speed networks. Modern digital technologies have vastly increased our capacity to know and to do things and to communicate and collaborate with others. They allow us to transmit information quickly and widely, linking distant places and diverse areas of endeavor in productive new ways. This technology allows us to form and sustain communities for work, play, and learning in ways unimaginable just

a decade ago. Of course, our nation has been through other periods of dramatic technology-driven change, but never before have we experienced a technology that has evolved so rapidly, increasing in power by a hundred-fold every decade, obliterating the constraints of space and time, and reshaping the way we communicate, think, and learn.

Furthermore, whether through travel and communication, through the arts and culture, or through the internationalization of commerce, capital, and labor, the United States is becoming increasingly linked with the global community. The world and our place in it have changed. A truly domestic United States economy has ceased to exist. It is no longer relevant to speak of the health of regional economies or the competitiveness of American industry, because we are no longer self-sufficient or self-sustaining. Our economy and many of our companies are truly international and are intensely interdependent with other nations and other peoples.[4]

This internationalization also continues to take place within our borders, as we are nourished and revitalized by wave after wave of immigrants who bring unbounded energy, hope, and faith in the American dream. Today, America is evolving into a "world nation" not only in terms of its economic and political ties, but also in terms of the ethnic ties many of our citizens share with parts of the globe. From this perspective, it becomes clear that understanding cultures other than our own has become necessary, not only for personal enrichment and good citizenship, but for our very survival as a nation.

The increasing diversity of the American work-force with respect to race, ethnicity, gender and nationality presents a similar challenge. Women, minorities, and immigrants now account for roughly 85 percent of the growth in the labor force, currently representing 60 percent of all of our nation's workers. The full participation of currently underrepresented minorities and women is crucial to our commitment to equity and social justice, as well as to the future strength and prosperity of America. Our nation cannot afford to waste the human talent, the cultural and social richness, represented by those currently underrepresented in our society. If we do not create a nation that mobilizes the talents of all our citizens, we are destined to play a diminished role in the global community and will in all likelihood see an increase in social turbulence. Most tragically, we will have failed to fulfill the promise of democracy upon which this nation was founded.

The growing pluralism of our society is both one of the greatest strengths and greatest challenges as a nation. The challenge of increasing diversity is complicated by social and economic factors. Far from evolving toward one America, our society continues to be hindered by the segregation and non-assimilation of minority cultures.

Both the courts and legislative bodies are now challenging long-accepted programs such as affirmative action and equal opportunity. Our social pluralism is among our most important opportunities, because it gives us an extraordinary vitality and energy as a people. As both a leader of society at large and a reflection of that society, the university has a unique responsibility to develop effective models of multicultural, pluralistic communities for our nation. We must strive to achieve new levels of understanding, tolerance, and mutual fulfillment for peoples of diverse racial and cultural backgrounds both on our campuses and beyond. But it has also become increasingly clear that we must do so within a new political context that will require new policies and practices.

The age of knowledge, globalization, changing demographics…all forces that are demanding change in the nature of education and educational institutions such universities. To illustrate, I am going to make several observations concerning the future of education from three different altitudes:

1. First, at the tree-tops level, I will discuss the changing nature of engineering education.

2. Then climbing to the 30,000 ft level, I will broaden my perspective to make some comments concerning the changing nature of undergraduate education.

3. And finally, from the L-1 point, a million miles from the Earth when one can see the entire globe, I will offer several conjectures concerning the future the learning needs of our society in the century ahead.

The Challenges to Engineering Education

Study after study has suggested that dramatic change is necessary in engineering education. There have been dozens of conferences and reports, major programs such as the NSF Engineering Coalitions and Systemic Initiatives efforts, and hundreds of efforts by individual engineering schools.[5] Even professional societies have called for reform, e.g., through the new Engineering Criteria 2000 requirements of the Accreditation Board on Engineering and Technology (ABET).

Despite these efforts, many today believe that engineering education remains trapped in a mid-20th Century paradigm[6] (or perhaps even a late 19th Century paradigm, if my archeological discoveries about similarity between early engineering curricula and today's offerings are correct). We continue to provide a form of engineering education,

which, while familiar from our own educational experiences, is increasingly irrelevant to the changing needs of a profession—not to mention a society—that is already far beyond our universities. Let me list some of the more apparent issues and concerns:

The Changing Nature of Engineering Practice

Today, engineering practice is evolving rapidly in response to a rapidly changing world. The shifting nature of national priorities from defense to economic competitiveness, the impact of rapidly evolving information technology, the use of new materials and biological processes—all have had deep impact on engineering practice. Put another way, the shift of our society from guns to butter, from transportation to communication, from atoms to bits, means that today's engineering students will spend most of their careers coping with challenges and opportunities vastly different from those most currently practicing engineers—or currently teaching faculty—have experienced.

While engineers are expected to be well grounded in the fundamentals of science and mathematics, they are increasingly expected to acquire skills in communication, teamwork, adaptation to change, and social and environmental consciousness. It is also clear from this perspective that engineering education simply has not kept pace with this changing environment. It is only a slight exaggeration to say that our students are currently being prepared to practice engineering in a world that existed when we, as their faculty, were trained a generation or two ago. They are not being prepared for the 21st Century.

From Specialization to Integration

The intellectual activities of the contemporary university are partitioned into increasingly specialized and fragmented disciplines. Perhaps reflecting the startling success of science in the 20th Century, most disciplines are reductionist in nature, focusing teaching and scholarship on increasingly narrow and specialized topics. While this produces graduates of great technical depth, it is at a certain sacrifice of a broader, more integrated education. This is particularly true in science-based disciplines such as engineering. The old saying is not far off the mark, "A Harvard graduate knows absolutely nothing about absolutely everything. An MIT graduate knows absolutely everything about absolutely nothing!"

We must question the value of narrow specialization at a time when engineering practice and engineering systems are becoming large, more complex, and involving components and processes from widely dispersed fields. Many believe that the most important intellectual problems of our time will not be addressed through disciplinary specialization but rather through approaches capable of integrating many different areas of knowledge—through "big think" rather than "small think".

Ironically enough, the essence of engineering practice is the process of integrating knowledge to some purpose. Unlike the specialized analysis characterizing scientific inquiry, engineers are expected to be society's master integrators, working across many different disciplines and fields, making the connections that will lead to deeper insights and more creative solutions, and getting things done. Thus, engineering education is under increasing pressure to shift away from specialization to a more comprehensive curriculum and broader educational experience in which topics are better connected and integrated.

Learning for Life

As the knowledge base in most engineering fields continues to increase at an ever more rapid rate, the engineering curriculum has become bloated with technical material, much of it already obsolete. Most undergraduate engineering programs have already become almost five years in length for most students. Even with this increasing technical content, most engineers will spend many months if not years in further workplace training before they are ready for practice. Furthermore, the effort to include the new technical knowledge in many fields, while retaining as well much of the old, has squeezed out other important curriculum content in areas. For example, at the University of Michigan, the humanities and social sciences component of the undergraduate curriculum has dropped to less than twenty credit hours, with as low as two credit hours of free electives in some engineering majors.

We simply have to accept the fact that it is no longer possible (if it ever was) for an engineering student to learn all they need to know during their undergraduate studies. Acquiring the array of technical knowledge and experience is a lifetime goal and requires a personal commitment to continual learning. An undergraduate engineering education should be viewed as only the initial launch for a career, designed to place the student in a lifetime orbit of learning.

The Professional Degree

As the growth of technical knowledge accelerates and the undergraduate engineering curriculum becomes more bloated and strained with new technical content, it becomes ever more apparent that it is simply no longer possible to regard the baccalaureate degree as sufficient for professional practice. Today, engineering is one of the very few professions that require only an undergraduate degree for professional status. Most other knowledge-intensive professions such as law, medicine, and even business, utilize graduate programs built upon a diversity of undergraduate majors. Little wonder that the status of engineers lag somewhat behind those of other professionals with more advanced education.

The inadequacy of the baccalaureate degree for professional practice is becoming apparent to employers as well. There is an increasing trend to hire graduates at the masters or even Ph.D. level for technical work, while relying upon baccalaureate engineering graduates for supporting services such as sales and technical support. Although study after study has recommended that the masters degree become the accepted route into the engineering practice, this continues to be resisted both by the profession and the academy.

Curriculum Reform

There is little doubt that the current sequential approach to engineering education, in which the early years are dominated by science and mathematics courses with engineering content deferred to the upper-class years, discourages many capable students. Students have little opportunity to find out what engineering is all about until late in their undergraduate studies. It is not unusual to find students wandering into our counseling and placement offices in their senior year, still trying to find out what they are majoring in and what they can do with an engineering degree. Compounding this is the fragmentation of the current curriculum, consisting of highly specialized and generally unconnected and uncoordinated courses, whose relationship to one another and to engineering education is rarely explained. Although everyone agrees that the undergraduate curriculum should focus on the fundamentals, few can agree on just what content is truly fundamental.

While the rigor of the scientific and mathematics foundation of modern engineering is important, it must be augmented by the broader contextual and integrative approach characterizing engineering practice. Students must gain

experience not only in solitary analysis but also in group work and hands-on "design-build-operate" projects. We must strive to integrate real design and process understanding into the educational system. Above all, we must challenge our students to think, to create, and to understand excellence.

Shifting Careers

In today's world of change, most graduates will find themselves frequently changing not only jobs, but entire careers. We already find that only about fifty percent of engineering graduates will enter technical careers, and after five years, about half of these will have moved into other areas such as management or sales. Put another way, most engineering graduates of today will find themselves in engineering practice for only a relatively short period, if at all.

Yet the increasing importance of technology to our world has made an engineering degree an excellent preparation for many other careers and professions: business, law, medicine, consulting, and government service, to name only a few. This poses a particular challenge to engineering educators, since they still focus primarily on educating students for the engineering profession.

Instead, as Roland Schmitt, former chair of theNational Science Board and president of RPI has noted, we must enlarge the very concept of the engineer to cover a wider range of human activities than every before. Engineering educators must begin by realizing that it is their duty to educate the leaders of our society as well as to educate the professional engineer. We should develop and promote a new kind of engineering education as a form of "liberal education" for the 21st Century. This will require new objectives and new curricula, some radically different that those of today because of a radically different objective: educating not simply professional engineers but a new breed of graduates with an engineering-based, liberal education.

The Faculty

Engineering faculties are almost unique among those of professional schools since they generally have little experience or activity in professional practice. The strong research focus of most engineering schools has led to a cadre of strong engineering scientists, able at generating new knowledge but relatively inexperienced in professional practice. Furthermore, engineering faculty are judged and rewarded by criteria appropriate to science faculty. Indeed, professional practice is not only absent in

promotion and reward criteria, but frequently discouraged. The faculty reward system recognizes teaching, research, and service to the profession, but it gives little recognition for developing a marketable product or process or designing an enduring piece of the nation's infrastructure.

It would be hard to imagine a medical school faculty comprised only of biological scientists rather than practicing physicians or music school faculty comprised only of musicologists rather than performing artists. Yet such detachment from professional practice and experience is the norm in engineering education.

The Responses Thus Far

Engineering educators, professional societies, and federal funding agencies such as the National Science Foundation have not been insensitive to these concerns. Following an intensive dialog among engineering deans, professional societies, and the Accreditation Board of Engineering and Technology has significantly restructured its criteria for accreditation of undergraduate engineering education.[7] The new Engineering Criteria 2000 includes, among other elements, criteria which stress the important of an engineering graduate's ability to:

1. Apply knowledge of science, mathematics, and engineering
2. Design and conduct experiments and analyze data
3. Design a system, component, or process to meet desired needs
4. Function on multi-disciplinary teams
5. Identify, formulate, and solve engineering problems
6. Understand professional and ethical responsibility
7. Communicate effectively
8. Understand the impact of engineering solutions in a global/social context
9. Engage in life-long learning
10. Exhibit a knowledge of contemporary issues
11. Use the techniques, skills, and modern engineering tools necessary for engineering practice.

The new ABET criteria also allow greater flexibility on the part of engineering schools to innovate and experiment with new approaches to engineering education.

The National Science Foundation has also played an important role in the modernization of the engineering curriculum. As the science and engineering education

activities of the NSF were restored during the late 1980s after devastating cuts earlier in the decade, engineering education had a high priority. Not only were programs launched encouraging curriculum innovation, but a broader set of initiatives aimed at systemic change were launched such as the Engineering Coalitions Program. Furthermore, a broad range and studies and workshops were sponsored to better define the nature of the "new engineering education" appropriate for the 21st Century.

These studies were remarkably consistent in the attributes they recommended for the new breed of engineering graduates. All agreed that sea change in engineering education would require a concurrent change from the predominant engineering school academic culture based on compartmentalization of knowledge, individual specialization, and a research-based reward structure to one that values integration as well as specialization, teamwork as well as individual achievement, and educational research and innovation as well as research in the engineering sciences. These studies suggested a new set of goals for engineering education:

1. To offer a broad liberal education that provides the diversity and breadth needed for engineering
2. To prepare graduates for entry into careers and further study in both the engineering and nonengineering marketplace
3. To develop the motivation, capability, and knowledge base for lifelong learning

This will require a very major change in the engineering curriculum. To some degree, it will require modernizing the science and mathematics instruction, e.g., recognizing that discrete rather than continuous mathematics is the foundation of the digital age, that biology and chemistry are rapidly becoming more important than physics, that new materials and processes have made obsolete much of the traditional curriculum. Beyond these technical changes, the NSF studies recognized that the new engineering curriculum must reflect a broad range of concerns, including environmental, political, social, international, and legal and ethical ramifications of decisions. Although the technical component would continue to be the core of an engineering education, the economic, political, social, and environmental context of engineering practice needs to be explicitly addressed.

Joseph Bordogna, Deputy Director of the National Science Foundation and former dean of engineering at the University of Pennsylvania identifies the skill set of the new engineering[8] as:

- Engineering science (analysis)
- Systems integration (synthesis)
- Problem formulation as well as problem solving
- Engineering design
- The ability to realize products
- Facility with intelligent technology to enhance creative opportunity
- Ability to manage complexity and uncertainty
- Teamwork (sensitivity in interpersonal relationships)
- Language and multicultural understanding
- Ability to advocate and influence
- Entrepreneurship and decision making
- Knowledge integration, education, and mentoring

Beyond that, engineering education should move away from the current dominance of classroom-based pedagogy to more active learning approaches that engage problem-solving skills and team building. Bordogna recalls the old Chinese proverb:

> I hear and I forget.
> I see and I remember.
> I do and I understand. [9]

This is apt indeed for engineering education. As a recent NSF workshop put it, the ubiquitous lecture is the bane of true learning, especially in observation-based, hands-on fields such as engineering. The lecture-dominated system encourages a passive learning environment, a highly compartmentalized (lecture-sized) curriculum, and worst of all, instills neither the motivation nor the skills for life-long learning. The dependence on the standard lecture must be diminished with emphasis given instead to discovery-oriented learning. We must create discovery-oriented learning environments that capitalize on the full power of new communication, information, and visualization technologies."

Undergraduate engineering programs can no longer ignore the fact that they simply cannot provide all the necessary knowledge for graduates to remain competitive throughout their careers. Content-based learning alone must not drive engineering education. The primary aim should be instead to instill a strong knowledge of how to learn, while still producing competent engineers who are well-grounded in engineering science and mathematics and have a understanding of design in the social context.

Engineering schools must educate the student for a lifetime of learning rather than just for their initial job. Students must learn how to learn, and they must be able to assess their skills and educational needs throughout their many careers. As Peter Drucker puts it, "We are redefining what it means to be an educated person. Traditionally an educated person was someone who had a prescribed stock of formal knowledge. Increasingly an educated person will be someone who has learned how to learn and who continues to learn throughout his or her lifetime."

Why Is Change So Slow?

Despite this broad effort, change in engineering education has been modest, as reflected in the tone of frustration in the recent remarks of Bill Wulf, President of the National Academy of Engineering: "We have studied engineering reform to death. While there are differences among the reports, the differences are not great. Let's get on with it! It is urgent that we do!"

Who is holding back change? Professional societies and accreditation agencies such as ABET? No, we have seen that they have become important forces of change.

What about industry? To be sure there is still a good deal of myopia among the recruiters that visit our placement office, all too often reinforcing very narrow definitions of student majors and abilities. Yet at high levels of management, there is strong awareness of the need for a broader form of engineering education. In a recent survey of CEOs conducted by the Business Higher Education Forum, it was found that the qualities valued most highly in graduates were not specific technical knowledge or skills but rather:

1. The ability to communicate well
2. A commitment to lifelong learning
3. The ability to adapt to an increasingly diverse world
4. The ability not only to adapt to change but to actually drive change

What about the faculty itself? To be sure, change is sometimes a four-letter word on university campuses. It is sometimes said that universities change one grave at a time. Judging from my comparison of the engineering curriculum of a century ago, even this may be too optimistic for engineering education. In fact, engineering educators do tend to be very conservative with regard to pedagogy, curriculum, and institutional attitudes. This conservatism produces a degree of stability (perhaps

inflexibility is a more apt term) that results in a relatively slow response to external pressures.

For the past several decades, the emphasis of engineering education has been focused on the scientific foundation of engineering knowledge. In part this had to do with the impact of modern science on technology. But it was also due to the culture of the research university, in which engineering faculty were evaluated based on their performance in fundamental research rather than engineering practice. Many believe this emphasis on research also has eroded the quality of teaching in engineering schools. In fact, a recent conference of young faculty suggested that most engineering schools not only fail to support adequately but also outright discourage faculty achievements in teaching, instructional scholarship, and public service. Tenure and promotion criteria do not encourage faculty to aspire to broad scholarly achievements, especially innovation, nor to contributions to public understanding.

How Can We Accelerate Change?

In the spirit of stimulating debate and thought, let me suggest a few more Draconian actions designed both to shake up and transform engineering education:

Eliminate all specialized engineering majors

The ever more narrow specialization among engineering majors is driven largely by the reductionist approach of scientific analysis rather than the highly integrative character of engineering synthesis. It may be appropriate for basic research, but it is certainly not conducive to the education of contemporary engineers nor to engineering practice. Although students may be stereotyped by faculty and academic programs—and perhaps even campus recruiters—as electrical engineers, aerospace engineers, etc., they rapidly lose this distinction in engineering practice. Today's contemporary engineer must span an array of fields, just as modern technology, systems, and processes.

Perhaps it is time to go even further and simply abandon the concept of an undergraduate engineering major and instead provide a general engineering curriculum, much as in other professions such as medicine, law, and business. Like these professions, one could leave specialization until later, provided either through graduate study or on-the-job training.

In fact, one might conjecture that in a future characterized by lifelong learning, perhaps engineering will rapidly evolve along the lines of other learned professions and shift professional education and training entirely to the graduate level, eliminating the undergraduate engineering degree altogether. There are strong reasons to suspect that a broad, liberal education is just as important for engineering practice as it is for other professions such as medicine and law. (Here one could also make the case for significantly greater technical and scientific content in the contemporary liberal arts curriculum.)

Shift away from the classroom to more suitable forms of pedagogy

Although science and engineering are heavily based on laboratory methods, in fact they are usually taught through classroom lectures coupled with problem-solving exercises. Contemporary engineering education stresses the analytic approach to solving well-defined problems so familiar from science and mathematics—not surprising, since so many engineering faculty members received their basic training in science rather than engineering.

To be sure, design projects required for accreditation of engineering degree programs are introduced into advanced courses at the upper-class level. Yet design and synthesis are quite small components in most engineering programs.

Clearly those intellectual activities associated with engineering design—problem formulation, creativity, innovation—should be introduced throughout the curriculum. This will require a sharp departure from classroom pedagogy and solitary learning methods. Beyond team design projects, engineering educators might consider adopting the case method approaches characterizing business and law education. More use might be made of internships as a formal part of the engineering curriculum, whether in industry or perhaps even in the research laboratories of engineering faculty where engineering design is a common task.

Attract more practitioners into engineering education

It is absolutely essential to broaden the engineering faculty to include practitioners. One approach would be to work with industry to persuade and allow senior engineering staff to accept faculty appointments. In fact, many retired engineers would make ideal faculty members, bringing their wealth of experience in engineering practice not only to the students but to the reshaping of the current science-driven

culture of engineering schools. Of course, this would require a very significant restructuring of the faculty promotion and reward systems. It might even lead to the elimination of tenure, at least in some components of engineering education. But the mix of practitioners and scholars has been both accepted and constructive in most other professional schools—medicine, law, business, architecture, and the fine arts. It seems high time to bring engineering education into line.

Broaden the perspective of engineering education

As we noted earlier, engineering educators should be challenged to devise an engineering-based "liberal education" for students of the 21st Century. Engineering principles and modes of thought should be the centerpiece of what the liberally educated person should know in the age of knowledge that is our future. We should produce graduates for all careers—from industry to law to government—with an education attuned to the issues and challenges of a knowledge-driven society, many of which have dominant technical themes.

The Challenge of Undergraduate Education for a World of Change

Let me now step back and offer some observations about the nature of undergraduate education more broadly.

The Purpose of an Undergraduate Education

What should be the aim of undergraduate education? Should we adopt Cardinal John Henry Newman's classic vision of a college education that "includes the great outlines of knowledge, the principles on which it rests, the scale of its parts, its light and its shades, its great points and its little, so that it produces an inward endowment, a habit of mind of which the attributes are freedom, equitableness, calmness, moderation and wisdom".[10] Or perhaps as Derek Bok, former President of Harvard, put it, the most important product of an undergraduate education in a changing, fragmented society may be "a critical mind, free of dogma but nourished by humane values."[11]

Yet to most students and parents, the purpose of a college education is to earn the college degree necessary for a good job, for personal economic security and well-being. Many of today's students approach their college education with very definite career goals in mind. They enroll with plans to become doctors or engineers or lawyers or teachers.

While many will change their minds during their undergraduate years, almost all will emerge with quite specific career goals still uppermost in mind.

Employers reinforce this utilitarian approach. The recruiters companies send to campus are looking for very definite skills. Perhaps they seek something highly specific such as a particular undergraduate major or Internet navigation skills. Or perhaps they seek some evidence that the student can communicate well and work comfortably in a diverse environment. Students are extremely sensitive to these signals from the employment marketplace, and the experience other students have with job interviews and placements can have a very significant impact on their own educational plans. In sharp contrast, however, surveys of business leaders suggest that they seek something quite different than practical knowledge or utilitarian skills from college graduates.[12] As I noted earlier, they seek graduates who exhibit strong communication skills, a capacity for and commitment to lifetime learning, a tolerance for diversity, and an ability to adapt to change–characteristics more associated with a liberal education than a professional program of study.

In a sense, the university is caught between the contradictory forces of responding to more pragmatic goals of students and employers while providing the liberal education that equips a student with the broader skills important for good citizenship and a meaningful life. Furthermore, in a world of ever-changing needs, one objective of an undergraduate education certainly must be to prepare a student for a lifetime of learning. The old saying that the purpose of a college education is not to prepare a student for their first job but rather their last job still has a ring of truth.

To be sure, the notion of a liberal education for the twenty-first century will be different than that characterizing our times. There has already been a radical change in undergraduate majors over the past several decades. For example, today only 13% of undergraduates major in the humanities, 7% in the sciences, and 15% in the social sciences. Perhaps this is a reflection of the belief that students view today's post-modernized and deconstructed humanities programs as largely irrelevant to their lives: the sciences are far more relevant, but also far too difficult for those increasingly ill-prepared by their K-12 education; and the social sciences are seen as somewhat relevant and suitably soft.[13] Most of today's undergraduates prefer instead more professional and marketable majors such as business, accounting, and engineering. And the cafeteria curriculum favored by most universities provides them with the opportunity to cascade through a jumble of courses during their undergraduate studies without structure, rigor, or liberal purpose.

As difficult as it is to define and as challenging as it is to achieve, perhaps the elusive goal of liberal learning remains the best approach to prepare students for a lifetime of learning and a world of change. After all, a college education should prepare one for life, and a career is only one of life's experiences.

The Plug-and-Play Generation

Despite the great diversity in colleges and universities, in learning environments, and in curricular content, most of us have a very specific notion of an undergraduate degree program. Stated in the most simplistic terms, this consists primarily of four years of study, divided into thirty semester hours a year, five courses per semester. These courses are selected to meet either the requirements of a particular area of concentration or major (e.g., psychology or physics or engineering) or from more general survey courses designed to broaden one's education. Most of these courses are taught in a lecture format, augmented by occasional seminars, discussion sections, and laboratories.

The classroom paradigm is being challenged today, not so much by the faculty, who have by and large optimized their teaching effort and their time commitments to a lecture format, but by our students. Today's students are different from earlier generations. They are citizens of the digital age. They have spent their early lives surrounded by robust, visual, interactive media—not the passive broadcast media, radio and television, of our youth, but rather Nintendo, home computers, the Internet, MUDs and MOOs, and virtual reality. They learn by experimentation and participation, not by listening or reading passively. They take no one's word for anything. Rather they embrace interactivity, the right to shape and participate in their learning. They are comfortable with the uncertainty that characterizes their change-driven world.

For a time, such students may tolerate the linear, sequential lecture paradigm of the traditional college curriculum. They still read what we assign, write the required term papers, and pass our exams. But this is decidedly not the way they learn. They learn in a highly nonlinear fashion, by skipping from beginning to end and then back again, and by building peer groups of learners, by developing sophisticated learning networks. In a very real sense, they build their own learning environments that enable interactive, collaborative learning, whether we recognize and accommodate this or not.

However, their tolerance for the traditional classroom and four-year curriculum model may not last long. Students will increasingly demand new learning paradigms more suited to their learning styles and more appropriate to prepare them for a lifetime of learning and change

The reality of our new students, diverse and often technically savvy, requires new educational approaches. Encouragingly, our growing base of technology has begun to create the possibility of new, more flexible roles for both students and faculty, within and beyond the classroom, allowing more interactive learning, and giving students the ability to interrogate or even create knowledge instead of simply absorbing it.[14] The new knowledge media may fundamentally change what it means to be a professor and a student at our universities. In these new learning paradigms, the word *student* becomes largely obsolete, because it describes the passive role of absorbing content selected and conveyed by teachers. Instead we should probably begin to refer to the clients of the twenty-first-century university as active *learners,* since they will increasingly demand responsibility for their own learning experiences and outcomes.

In a similar sense, the concept of a faculty member as a *teacher* who develops and presents knowledge to largely passive students may become obsolete. Faculty members of the twenty-first-century university may find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes, and environments. In the process, tomorrow's faculty members may have to discard the present style of solitary learning experiences, in which students tend to learn primarily on their own through reading, writing, and problem solving. Instead, they may be asked to develop collective learning experiences in which students work together and learn together, with the faculty member becoming more of a consultant or a coach than a teacher. In these new paradigms the role of the faculty member becomes that of nurturing and guiding active learning, not of identifying and presenting content. That is, they will be expected to inspire, motivate, manage, and coach students.

Broadening the Elements of Undergraduate Education

Today we see an important shift in education from a focus on teaching knowledge and skills to a focus on active student learning. Increasingly, learning occurs not simply through study and contemplation but through the active discovery and application of knowledge. There is a certain irony here. The contemporary university provides one of the most remarkable learning environments in our society—an extraordinary array of diverse people with diverse ideas supported by an exceptionally rich array of intellectual and cultural resources. Yet we tend to focus most of our efforts to improve undergraduate education on traditional academic programs, on the

classroom and the curriculum. In the process, we may have overlooked the most important learning experiences in the university.

Think about it from another perspective. When asked to identify the missions of the university, university faculty and administrators generally respond with the time-tested triad: teaching, research, and service. Undergraduate education, however, is usually thought of only from the perspective of the first of these missions, teaching. Clearly, we should broaden our concept of the undergraduate experience to include student involvement in other aspects of university life.

For example, in most research universities there is an ever-widening gap between the research activities of the faculty and the undergraduate curriculum. Although research universities possess a rich array of intellectual resources, through their scholars, laboratories, and libraries, little of this is made available to undergraduates. We should challenge the American research university to develop new models of undergraduate education that take advantage of the extraordinary intellectual assets of these institutions. Perhaps every undergraduate should have the opportunity—or perhaps even be required—to participate in original research or creative work under the direct supervision of an experienced faculty member. Those few students who have been fortunate enough to benefit from such a research experience usually point to it as one of the most important aspects of their undergraduate education, unfortunately most receive their education only through the more standard curriculum. Interestingly enough, many faculty members who have supervised undergraduate research projects also find it to be an exhilarating role, because undergraduate students are frequently more questioning and enthusiastic than graduate students!

There is ample evidence to suggest that student learning also benefits significantly from participating in community or professional service. Such activities provide students with experience in working with others and applying knowledge learned in formal academic programs to community needs. Many students arrive on campus with little conception of broader community values, and the experience of doing something for others can be invaluable.

Knowledge is created, sustained, and transformed in "communities of practice."[15] While there are numerous opportunities for volunteer community service at all universities, a more structured approach would better align these experiences with the goals of an undergraduate education. Such community or professional service might even be considered as a requirement for an undergraduate degree.

The undergraduate experience must be reconsidered from a far broader perspective, encompassing the multiple missions of the university. All too frequently each of the missions of the university is associated with a different component; a liberal education and teaching with the undergraduate program, research with the graduate school, and practical service with professional schools. In reality, all components of the university should be involved in all of its missions—particularly undergraduate education.

Lifelong Learning

Perhaps part of our difficulty in reconceptualizing the undergraduate experience is that we still tend to think of the baccalaureate degree as a well-defined learning experience that prepares a student for life. But today learning has become a lifelong activity. Today's students will need to continue to learn, through both formal and informal methods, throughout their lives.

Of course, a college education was never intended to provide all of the knowledge needed for a lifetime. But in years past, most of the additional knowledge necessary for a career could be acquired informally, through on the job learning or self-study. Today, however, both rapid growth of knowledge and the multiple career transitions facing graduates demand a more strategic approach to lifetime learning. We need to rethink educational goals from this lifetime perspective. We should view undergraduate education as just one step—an important step to be sure—down the road of a lifetime of learning. This would allow us to better match learning content and experiences with both the intellectual maturation and the needs of the learner.

In a world driven by knowledge, learning can no longer be regarded as a once-is-enough or on-again/off-again experience. People will need to engage in continual learning in order to keep their knowledge base and skills up to date. Given this need, the relationship between a student/graduate and the university may similarly evolve into a lifetime membership in a learning community. Just as we have suggested that the word *student* is no longer appropriate to describe an active learner, perhaps the distinction between student and *alumnus* is no longer relevant.

Perhaps the relationship between a university and its graduates that is more appropriate for our future is conveyed by the term *lifelong member of a learning community*. Perhaps enrollment should be viewed less as participation in a particular degree program and instead as a lifetime contract with the university, in which the university agrees to provide whatever learning resources are required by its learners or members throughout their life, whatever, whenever, and wherever their educational needs. Clearly, the rapid

evolution of distance learning technology will increasingly facilitate this. We also see increasing interest on the part of alumni in remaining connected to their university and to learning opportunities throughout their lives.

The Future of Undergraduate Education

So what is the future of undergraduate education? Clearly the classroom will not disappear. Nor will the residential campus experience of undergraduate education for young adults be overwhelmed by virtual universities or "edutainment." These traditional forms of pedagogy will remain valuable opportunities for learning for many in our population at certain formative times of their lives.[16]

These traditional models will coexist with new learning paradigms, providing a broader spectrum of learning opportunities in the years ahead. The transitions from student to learner, from teacher to designer/coach/consultant, and from alumnus to lifelong member of a learning community seem likely. And with these transitions and new options will come both an increasing ability and responsibility to select, design, and control the learning environment on the part of learners.

There will be strong pressures on universities to shift away from being faculty-centered institutions in which faculty determine what to teach, whom to teach, how to teach, and where and when to teach. Instead universities will likely evolve into learner-centered institutions, in which learners have far more options and control over what, how, when, where, and with whom they learn.

But the university will remain a place where future leaders are shaped and educated. The true purpose of undergraduate education will remain the broader intellectual development of the young, preparing them not simply for careers but for meaningful lives as contributing citizens.

A Society of Learning

Ask any governor about state priorities these days, and you are likely to hear concerns expressed about education and workforce training. The skills race of the 21st Century knowledge economy has become comparable to the space race of the 1960s in capturing the attention of the nation. Seventy percent of Fortune 1000 CEOs cite the ability to attract and retain adequately skilled employees as the major issue for revenue growth and competitiveness. Corporate leaders now estimate that the high performance workplace will require a culture of continuous learning in which as much as 20% of a

worker's time will be spent in formal education to upgrade knowledge and skills. Tom Peters suggests that the 21st Century will be known as the Age of the Great War for Talent, since in the knowledge economy, talent equals wealth.[17]

The signs of the knowledge economy are numerous. The pay gap between high school and college graduates continues to widen, doubling from a 50% premium in 1980 to 111% today. Not so well know is an even larger earnings gap for those with graduate degrees . The market recognizes this, as evidenced by a comparison of the market-capitalization per employee of three companies:

General Motors	$141,682
Walt Disney Company	$743,530
Yahoo	$33 million

In fact, the market-cap-per-employee of the top 10 Internet companies averages $38 million! Why? In the knowledge economy, the key asset driving corporate value is no longer physical capital or unskilled labor. Instead it is intellectual and human capital.

But here we face a major challenge, since it is increasingly clear that we are simply not providing our citizens with the learning opportunities needed for a 21st Century knowledge economy. Recent TIMMS[18] scores suggest that despite school reform efforts of the past two decades, the United States continues to lag other nations in the mathematics and science skills of our students. Despite the growing correlation between the level of one's education and earning capacity, only 25% of those in our population over the age of 25 have graduated from college. Furthermore, enrollments in graduate programs have held constant or declined (particularly in technical fields such as engineering) over the past two decades.[19]

The space race galvanized public concern and concentrated national attention on educating "the best and brightest," the elite of our society. The skills race of the 21st Century will value instead the skills and knowledge of our entire workforce as a key to economic prosperity, national security, and social well-being. Yet there is growing concern about whether our existing institutions have the capacity to serve these changing and growing social needs—indeed, even whether they will be able to survive in the face of the extraordinary changes occurring in our world.

As we enter the new millennium, there is an increasing sense that the social contract between our educational institutions and American society may need to be reconsidered and perhaps even renegotiated. We have entered an era in which educated people and the knowledge they produce and utilize have become the keys to the economic prosperity and well-being of our society. Education, knowledge, and skills have become primary determinants of one's personal standard of living.

Just as our society has historically accepted the responsibility for providing needed services such as military security, health care, and transportation infrastructure in the past, education today has become a driving social need and societal responsibility. It has become the responsibility of democratic societies to provide their citizens with the education and training they need, throughout their lives, whenever, wherever, and however they desire it, at high quality and at an affordable cost.

But even this may not be enough. Perhaps we should instead consider a future of universal and pervasive learning opportunities, for everyone, every place, all the time. Indeed, in a world driven by an ever-expanding knowledge base, continuous learning, like continuous improvement, has become a necessity of life. Rather than an "age of knowledge," we could instead aspire to a "society of learning," in which people are continually surrounded by, immersed in, and absorbed in learning experiences.

The great and ever-increasing diversity characterizing higher education in America makes it clear that there will be many forms, many types of institutions serving our society. But there are a number of themes that will almost certainly factor into at least some part of the higher education enterprise.

Just as other social institutions, our universities must become more focused on those we serve. We must transform ourselves from faculty-centered to learner-centered institutions, becoming more responsive to what our students need to learn rather than simply what our faculties wish to teach.

Society will also demand that we become far more affordable, providing educational opportunities within the resources of all citizens. Whether this occurs through greater public subsidy or dramatic restructuring of the costs of higher education, it seems increasingly clear that our society—not to mention the world—will no longer tolerate the high-cost, low-productivity paradigm that characterizes much of higher education in America today.

In an age of knowledge, the need for advanced education and skills will require both a personal willingness to continue to learn throughout life and a commitment on the part of our institutions to provide opportunities for lifelong learning. The concept of student and alumnus will merge.

Our highly partitioned system of education will blend increasingly into a seamless web, in which primary and secondary education; undergraduate, graduate, and professional education; on-the-job training and continuing education; and lifelong enrichment become a continuum.

Already we see new forms of pedagogy: asynchronous (anytime, anyplace) learning that utilizes emerging information technology to break the constraints of time and space, making learning opportunities more compatible with lifestyles and career needs; and interactive and collaborative learning appropriate for the digital age, the plug-and-play generation.

The great diversity characterizing higher education in America will continue, as it must to serve an increasingly diverse population with diverse needs and goals.

Concluding Remarks

Clearly higher education will flourish in such a future. In a knowledge-intensive society, the need for advanced education will become ever more pressing, both for individuals and society more broadly. Yet it is also likely that the university as we know it today—rather, the current constellation of diverse institutions comprising the higher education enterprise—will change in profound ways to serve a changing world. The real question is not whether higher education will be transformed, but rather *how . . .* and by *whom*. If the university is capable of transforming itself to respond to the needs of a society of learning, then what is currently perceived as the challenge of change may, in fact, become the opportunity for a renaissance, an age of enlightenment, in higher education in the years ahead.

For a thousand years the university has benefited our civilization as a learning community where both the young and the experienced could acquire not only knowledge and skills, but the values and discipline of the educated mind. It has defended and propagated our cultural and intellectual heritage, while challenging our norms and beliefs. It has produced the leaders of our governments, commerce, and professions. It has both created and applied new knowledge to serve our society. And it has done so while preserving those values and principles so essential to academic learning: the freedom of inquiry, an openness to new ideas, a commitment to rigorous study, and a love of learning.[20]

There seems little doubt that these roles will continue to be needed by our civilization. There is little doubt as well that the university, in some form, will be needed to provide them. The university of the twenty-first century may be as different from today's institutions as the research university is from the colonial college. But its form and its continued evolution will be a consequence of transformations necessary to provide its ancient values and contributions to a changing world.

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