Graduate Education in 2020

What Does the Future Hold?

Council of Graduate Schools

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COUNCIL OF GRADUATE SCHOOLS

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At the heart of the Graduate Education 2020 project is the intellectual contribution of speakers invited by CGS to present versions of commissioned papers at an annual symposia on the forces and factors that are likely to shape the future of graduate education. This volume represents contributions from three of the four speakers from the first two annual symposia that took place in December of 2006 and 2007 in conjunction with the CGS annual meeting. CGS thanks Chris Dede, David Baker, Anthony Carnevale, and Stephen Trachtenberg for their thoughtful and thought provoking contributions to those first two meetings. Because the Graduate Education 2020 symposium in 2008 was devoted to international themes, David Baker's paper on international trends in higher education will be published in the second collected volume alongside papers by Peter Scott and Christian Bode in 2009-2010. The introductory chapter to this volume, "Graduate Education in 2020: Forces Influencing Our Future," was prepared by CGS President Debra Stewart and staff members Daniel Denecke and Heath Brown.

FOREWORD

One distinguishing characteristic of effective leaders in all domains is that they spend at least some portion of their time thinking about the future and anticipating ways in which current trends and imminent changes outside their area of expertise might impact the future of their enterprise. This is true for chief executive officers and consultants, for politicians, and for graduate deans. Often embroiled in their day-to-day responsibilities, however, graduate deans may have little opportunity to reflect strategically on trends that promise to shape the future of the graduate education enterprise. The Council of Graduate Schools (CGS), with generous support from the Educational Testing Service, sought to remedy this problem by providing a formal occasion for such reflection with the launch of a 10-year project, "Graduate Education 2020." This project is convening some of the world's leading thinkers to look at trends affecting the future of graduate education, with special emphasis on examinations of these trends from a global perspective.

During the planning stages of this project, CGS prepared a white paper that speculates about some of the various scenarios within which current trends taking place across a variety of sectors have the potential to impact graduate education over the next several decades. Based on the responses and recommendations of an expert advisory committee, we are commissioning papers from some of the world's leading thinkers working in diverse fields such as: economics, innovation technology, educational research, population demographics, and globalization. Thought leaders from government, industry, and the media are represented here as well as academic scholars. The national conversation that is taking place around this project is helping institutions respond to inevitable future trends and assisting them in better understanding how to situate their efforts to improve graduate education in the broader context of the global knowledge-based society.

This first CGS Graduate Education 2020 publication contains a revised version of the original white paper that stimulated discussion among the advisory committee about possible contributors to this project and topics for original commissioned research. The three commissioned papers in this volume exhibit a wide range of topics, voices, and writing styles. Each tells a compelling story about the possible future for graduate education. Some of these papers are replete with data and examples, while others engage in more discursive "blue sky" thinking. What is common across all three is a willingness of the authors to accept CGS' challenge to step outside their normal comfort zone and take risks to speculate in an informed way about the future and graduate education. While the papers do not necessarily represent the views of CGS, the first two provide informative and provocative research perspectives on two sectors with enormous implications for the shaping of graduate education: the economy and technology, and the third paper provides a unique perspective on the need for continued innovation and entrepreneurship among university leaders.

The next volume, which will appear in late 2009 or early 2010, will be devoted to a topic of increasing importance in the graduate community: global factors shaping graduate education. The papers in that volume will include several perspectives on higher education trends in Europe that will affect graduate education in North America, including one paper from the first annual Graduate Education 2020 symposium and two other perspectives from the 2008 annual meeting. As this project evolves, CGS will be developing an interactive forum to encourage broad national discussion on these and other topics. We look forward to the engagement of each of you in the developing conversation about our collective future.

Debra W. Stewart, President
Council of Graduate Schools

Graduate Education in 2020: Forces Influencing Our Future

Debra W. Stewart, Daniel D. Denecke, Heath Brown[1]

I. Introduction

A thriving system of graduate education is essential to national prosperity in the U.S. and around the world. In the U.S. context it is the leaders of our graduate schools who are the major stewards of the graduate enterprise. The term "steward" is used deliberately, here. Two literal synonyms of the word are: warden and park ranger. And while it is certainly true that aspects of the graduate dean's job share common ground with both the warden (an official responsible for enforcing certain regulations) and the park ranger (one who provides oversight of a constantly growing and changing community, always on the look out for the random event that will bring harm to that community), the essence of the dean as "steward" goes beyond both. The term steward here is intended to connote the same meaning as Lee Schulman evokes when he talks of faculty as "stewards" of their disciplines: "The PhD is expected to serve as a steward of her discipline or profession, dedicated to the integrity of its work in the generation, critique, transformation, transmission and use of its knowledge" (Golde and Walker, 2006). The Graduate Dean as steward is dedicated to the integrity of the graduate education enterprise as it prepares students to explore and advance the limits of knowledge and define the state of the art in every field.

To designate graduate deans as stewards of the graduate enterprise is not to ignore its other significant stakeholders, both inside and outside the universities. Inside our institutions these are the presidents, provosts, other senior academic administration leaders, college deans, the faculty and of course the students. All of these people have invested their time, passions, and energies in the long term health of the enterprise. Likewise, outside the university our public "bankers," which include state legislatures, governors, U.S. Congress and the Executive Office, collectively exercise the ultimate power of the purse string to ensure their investments in graduate education are serving the public. Increasingly, the graduate education enterprise also relies upon private "bankers": from business and industry, who are interested in securing the long-term supply of talent, and private foundations whose broad missions may include strengthening education, fostering democracy, and solving global problems and who recognize graduate education's centrality to achieving all of these goals.

But despite the number, variety, and interest of stakeholders, it is the graduate dean who comes to work every day with the primary focus on the welfare of the graduate programs, their faculty and students. It is the dean who articulates a vision of excellence for the graduate community, provides ultimate quality control, maintains equitable standards across all academic disciplines, gives definition to graduate education, brings an institution-wide and interdisciplinary perspective, and serves as an advocate for issues and constituencies critical to the success of graduate programs.

As the stewards for graduate education on campus, graduate deans need to be vigilant on a daily basis for opportunities to advance the interest of graduate programs and students and for potential hazards that may threaten that interest. Such opportunities may arise within the university or they may arise outside. Graduate deans survey the present environment for opportunities to collaborate with other colleges, universities, and employers, regionally, nationally, and globally, because they understand that "in a rising tide all ships rise together." But effective stewardship means also developing a robust understanding of the future and consciously urging or taking actions now on campus that will prepare the graduate community for the changes that inevitably will come.

II. Mental Models Required for Effective Stewardship

There are several mental models of the future that will equip graduate school leadership to fulfill their stewardship obligations. These models fall into three categories. First, mental models that capture what futurist and business strategist Peter Schwartz calls the "inevitable surprises." The vast majority of these surprises are predictable because they have their roots in "the driving forces at work today" (Schwartz, 2003, p.3). These are things that we now could analyze based on the current drivers that will shape the process of graduate education in 2020. The problem is that there are so very many places to look. Our task is to shine light in the right obvious places. Labor force data provide one of the best examples. Projections of education supply and demand in the period 2002 to 2012 show an emerging deficiency in both bachelor's degrees and graduate degrees in the U.S. Analyzing Current Population Survey (CPS) and Bureau of Labor Statistics (BLS) data, for example, researcher Tony Carnevale has projected a shortage of approximately 10,000 post-baccaulaureate degrees by 2012 (Carnevale, 2005). Projections about the future are always debated, but they are valuable because they are based on current enrollment trends and demographic realities. In his contribution to this volume (Chapter 2), Carnevale expands upon his projections of future employment needs and addresses some of the shortcomings of prevailing models for estimating future workforce demand. The bulk of this introductory chapter (section III, below) discusses an array of "inevitable surprises" in the areas of demographics, graduate reform initiatives, the changing balance of public and private support of graduate education, and the acceleration of global competition.

The second mental model of the future identifies important "unknown" domains—the things that might be foreseeable, and if they occur would result in "transformational events," but are not already predetermined. The task here is to look far outside the box to factors that might radically alter our current practices in graduate education. Here the most accessible examples come from the work of technology futurists. For example, Ray Kurzweil argues that by the year 2030 accelerating technology will lead to "super human machine intelligence," to the merger of biological and non-biological intelligence (Kurzweil, 2005). While 2030 is a decade beyond our proposed time frame, clearly such a development would radically alter the practice of graduate education as we know it today. Although the technologies that would make such a merger possible are just beginning to surface, the shape and implications of this merger are the unknowns, and the change would be transformational. Section IV below provides some of the possible outlines of our unknown domains.

The third model is the one that aids graduate deans and all academic leaders as they try to sort through this mélange of information, opinion and fact to develop a "futures management plan." Such a model would provide some sense of the directions for future thinking, the conversations that need to be launched, the coalitions that need to be built, and some ordering of the actionable items from all of the issues surfaced above. This action plan should be accessible to and useful both for deans on CGS campuses and for deans acting collectively through CGS. Through this publication and as this project develops, we hope to generate ideas that will enable graduate education's stakeholders to respond to the future we anticipate and to shape the future we desire.

III. The Inevitable Surprises

A. Demographic trends

On the surface, the most inevitable feature of graduate school in America in 2020 is the composition of its population. We have a good notion of the possible ethnic, racial, and gender distribution and, given the demographic trends that enable us to predict these characteristics, of the limit to that population's growth. Assuming that some characteristics of the university remain constant, we have a reasonably good idea about the pool of future U.S. graduate students because all of the possible candidates were born in or before 1998.

If we were talking about projecting the number of college freshman, we could be a bit more specific. We know roughly how many students there will be to fill college freshman classes because the vast majority of college freshmen are 18 year olds. Those 2020 college freshmen were born in 2002. The challenge with projecting graduate enrollments is that we can no longer assume a fixed age for the beginning graduate student. A decade ago, CGS research noted a sea change underway in graduate education from the traditional population of students moving from the bachelor's degree directly to graduate education to a population marked by older returning students (Syverson, 1995). Given the fact that the vast majority of American graduate students cluster between 20 and 54, and only about half are between the ages of 25 and 34, the "college freshman model" for predicting the demographic composition of graduate students is of little value. Age was not the only "inevitable surprise" in the changing characteristics of the graduate education population; the gender, employment status, marital status, number of dependents, and student loan debt of the new graduate student was changing as well. In 1996, Peter Syverson described the new American graduate student as "a woman in her 30s pursuing a master's degree on a part-time basis, with a full-time job and typically married, often with responsibility for children and likely to have some education-related debt" (Syverson, 1996). Syverson's analysis of the same data source in 2002 yielded a similar picture with more ethnic diversity and still growing participation by women (Syverson, 2002).

An alternative approach is to look at workforce data. Here data on the worker gap prove most informative and suggest a major demographic challenge for the graduate enterprise. The demographic projections of native-born Americans suggest that their representation in graduate education has plateaued, and that continued growth in graduate enrollment is unsustainable unless a substantially higher percentage of native-born students choose to go to graduate school than in the past. The proportion of native-born Americans between 25 and 54 in the U.S. labor force increased by 54 percent in the two decades between 1980 and 2000, but this same group is projected to have a zero growth rate between 2000 and 2020 (Elwood, 2001). This is simply because the replacement (fertility) rate has dropped significantly, and that drop is expected to continue. If this is the case, the only way to continue to increase graduate participation of the kind we have seen since 1976 is to either significantly increase the percentage of Americans who go to graduate school or increase international enrollment (Pavel, et al. 2006).

To put this finding into a global context, we note that global population growth is highly stratified (Peterson, 2008). While the world population will grow substantially by 2020, the vast majority of that growth will be in countries least capable of supporting it. Life expectancy and quality of life will remain key challenges in the developing world. By contrast, the population of the entire developed world is contracting while, at the same time, life expectancy is increasing dramatically. The U.S. Census Bureau projects life expectancy to increase from 75.9 years in 1995 to 79.5 years in 2020 [http://www.census.gov/population/www/projections/2008projections.html].[2] The ageing population of all developed countries will place substantial pressure on the younger generations to sustain economic growth in a highly productive workforce, an outcome only achievable if the younger generations are highly trained to be the innovators and creators such levels of productivity require (Peterson, 2008)

Given the projected population trends in native-born American replacement fertility and life expectancy, what are the prospects for increasing the proportion of Americans going to graduate school between now and 2020? Looking only at some demographic trends it is clear that the American population of 20 to 64 year olds in 2020 will be substantially more diverse than that of today. While the white working age population in the U.S. workforce is expected to decline from 82 percent to 63 percent between 1980 to 2020, the minority population during that time is expected to double (and the Hispanic Latino portion to almost triple, from 6 percent to 17 percent) (NCPPHE 2005). [By 2050, a study by the Pew Research Center projects, the Hispanic population will comprise 29% of the overall U.S. population, up from 14% in 2005.] The dramatic impact that we are likely to see in the composition of the college freshman class of 2020 is that it will be a "majority minority" population (where the majority of students will be made up of so-called minority groups). Although the age range of the graduate population means that graduate education in 2020 will not reflect such a dramatic demographic shift, it is absolutely true that any growth that we see in native-U.S. participation in graduate education will have to come from minority growth. Recent trend data show that the participation of African-American, Hispanic, and American Indian groups in graduate education has grown at higher rates than those of white students over the last two decades.

Even with this dramatic growth of minorities in the college population, however, underrepresented minorities still participate in graduate education at a significantly lower rate than white Americans, for instance receiving less than 10 percent of the doctoral degrees. Without some substantial intervention, it is hard to believe that their proportional representation will increase beyond the rates we have seen over the last decade. This is compounded by the fact that the fastest-growing minority population in the U.S., Hispanics, also exhibit the lowest high school completion rates. If we do not devise an effective national strategy to increase access for minority students to graduate school beyond their current participation rate, overall participation in graduate education and the pool of potential domestic applicants will simply fall below where it is today.

One possible response is that, as unfortunate as this demographic story may be, the deficit of domestic students will be compensated for by a continuing growth in international student enrollment. For decades, the most talented students from around the world have flocked to U.S. universities. Graduate programs, nationally, receive on average upwards of five international applications for every available position, with many programs reporting application ratios of 30+ to one. Of course, these international students contribute significantly both to U.S. graduate programs and to the U.S. research enterprise. Ultimately, they make vital contributions either to the domestic workforce or to the stature of American universities as “ambassadors” of U.S. graduate education abroad.

In 2004, however, a Council of Graduate Schools study found a 28 percent decline in international applications to graduate school for fall 2004. And this decline in applications translated into a 6 percent decline in first-time international graduate enrollment for fall 2005—the third straight year of declines. Findings from subsequent CGS annual surveys show that the decline in international applications has bottomed out and in fact is turning around, though the recovery is slowing down (applications were up 11 percent from 2005 to 2006, and up 8 percent from 2006-2007)

[CGS, 2007; CGS, 2008]. The multi-year declines served as a loud wakeup call to those who assumed that U.S. graduate schools could always "fill-in" with international students. The growing capacity around the world to deliver graduate education (discussed below) will permanently change the competitive position of American graduate schools. By 2020, the standing of U.S. graduate education and its continued capacity to attract the best international talent will depend crucially on the success of the growth strategies of countries around the world.

B. Impacts of current reforms

A second "inevitable surprise" in 2020 will result from the flurry of efforts of U.S. graduate schools to "reform" graduate education at the end of the 20th and beginning of the 21st century. "A "quiet revolution" has occurred in U.S. graduate schools as graduate deans partner with other administrators and faculty. Stimulated by the publication of *A Silent Success: Master's Education in the United States* (1993) by Clifton Conrad et al., which presented research commissioned by the Council of Graduate Schools, and by the publication of a National Academies of Science report on *Reshaping the Graduate Education of Scientists and Engineers* (1995), an ongoing conversation about reform in graduate education has been taking place for more than a decade (NAS, 1995). The conversation has been fueled by a series of studies finding that while students reported substantial satisfaction with their graduate degree programs—indeed, most reported that they would choose to earn their degrees again—they raised many issues and concerns with the process and outcomes of the graduate experience. Students specifically demanded process improvements in preparation for teaching roles, faculty mentoring, and cross disciplinary learning, as well as preparation in a series of life skills, such as communication, negotiation, and professional ethics. Students also called for more clarity about career outcomes and a greater match between their graduate training and the careers they are likely to pursue upon graduation.

In the last few years America's graduate schools engaged in a number of experiments designed to improve the enterprise at both the master's and doctoral levels. Two of the most comprehensive are the PhD Completion Project and the Professional Master's Initiative. Through the PhD Completion Project, the Council of Graduate Schools, with support from Pfizer Inc and the Ford Foundation, is now in partnership with 46 universities as they work to implement a series of interventions designed to improve the quality of the doctoral experience, and in the process dramatically decrease doctoral attrition especially among minority and women students. The Professional Master's Initiative, with support from the Sloan and Ford Foundations, is enabling CGS to support graduate schools in their efforts to develop professional master's programs in traditional arts and science fields. These programs are designed to give the students skills and perspectives to succeed in the jobs they will obtain in the business, government or non-profit sectors while simultaneously ensuring they have the deep knowledge of the field research typically associated with advanced training in the discipline. Through such activities, the reforms underway in graduate education should produce results even in the near term, but certainly by 2020. And the efforts in public accountability and transparency for students that are at the heart of these reforms promise to modify the culture of doctoral and masters education by 2020 in ways that provide an even greater reconciliation between advanced research training, social needs, and the public interest than we see today. That there will be some impact is inevitable, though the details of the direction of change remain unclear.

C. The social-public function of graduate education

A third inevitable surprise will emerge from the continuing struggle to articulate the vision of graduate education as a public benefit, not simply as a private good. The value of graduate education as a private good is more directly grasped by graduate education's stakeholders than is the notion of graduate education as a public benefit. That graduate education is a private good is easy enough to demonstrate. We know for example that at the present time (compared to those with a bachelor's degree) there is a $10,000 premium in annual salary on average to workers with master's degrees, and an annual average additional increment of $20,000 for those with a doctorate (US Census Bureau, 2006, Table 9). Moreover, according the U.S. Census Bureau the wage premium paid for education is growing as evidenced by the earnings of those with high school diplomas, adjusted for inflation, remaining essentially unchanged over the last three decades ($29,389 in 1975 and $31,071 in 2006), whereas for those with advanced degrees (master's, doctorates, and professional degrees) earnings are increasing ($62,672 in 1975 and $82,320 in 2006) (ibid., Table A-3). We also know that a variety of characteristics people associate with a good work life are also highly correlated with the acquisition of advanced degrees—such characteristics as autonomy, control over one's career, and work satisfaction are all clear private benefits.

What is not so easy to document empirically is the public benefit of graduate education. Advanced degrees are highly correlated with public goods: volunteering, voting, and good health. In a society with the amenities that we all would like to see, the strong correlation suggests that citizenship is not only coincident with, but indeed fostered by graduate education. But most research has been unable, as of yet, to pinpoint the broader social and public benefits of graduate education specifically, in part because of the limitations of existing data sets, but also because the public benefits of innovation, invention, and scientific discovery are so long-term and diffuse. The public contributions of teachers, nurses, and social workers who earn graduate degrees are also considerable, but equally difficult to quantify.

In 2008, CGS published a national report on *Graduate Education and the Public Good* that highlights graduate degree holders whose far-reaching accomplishments in the sciences, business, government, education and the arts have positively affected millions of people, worldwide. This report served as the basis for a meeting hosted by CGS of graduate deans and senior legislators in the U.S. congress on the public benefits of graduate education. As important as the data in this report are the compelling anecdotal narratives of individual successes in the supplement to the report that provide irrefutable evidence of the broader public benefits of a graduate degree.

In part a result of the limited understanding of the full contribution of higher education, demands for "accountability" for public investment recur regularly in our state legislatures and range from alarm at the salaries of some highly compensated university administrators to concern over the extent to which particular political ideologies have overtaken our campuses. Accountability in graduate research funded by tax dollars is another area under greater scrutiny. As the number of research misconduct cases rises, universities are developing more active and more systematic educational responses to the issue. And accountability in responsible mentoring of students in graduate programs has also surfaced in public concerns about the average time students take to complete their degrees and the sub-optimal percentage of students who enroll in, but do not complete, their programs of study. While graduate deans are taking leadership roles in addressing each of these areas, there is still much work to be done to secure the public's perception of graduate education's broader benefits.

The strongest voices for the value of graduate education to society in the current environment come from segments of corporate America concerned with the future of the science and technology workforce. Recognizing that long-term ready access to an international talent pool is less dependable than it once was, the Council on Competitiveness and other corporate consortia stress that we must develop U.S. talent if America is to prosper. Beyond the corporate sector, however, the U.S. federal government remains ambivalent about renewing its commitment to making the development of graduate education and of R&D a national priority. It remains to be seen whether a strategic investment in higher education on the order of the 1958 National Defense Education Act will be forthcoming.

A highly evolved society needs highly trained people not just in science and technology but in all fields—elementary education teachers with master's degrees, social service professionals with advanced training, humanities PhDs who are positioned to interpret our past and help us think critically about our future. Significant constraint on the U.S. discretionary budget that has traditionally funded higher education may jeopardize those fields, however, for which private bankers in the corporate sector are not immediately forthcoming. In a world where the mobilization of bias is increasingly in the direction of private over public, the future training of scholars in the humanities, arts and some fields of social science will depend on a strong voice for the public benefit of their training.

Many recent studies of the national trends in education funding describe the current situation as a privatization of public higher education. Data demonstrate that real state and local support per student declined 12 percent over the period 1991-2004, with an acceleration to 16.8 percent in the last four years: "Public universities that used to cluster around the 50 percent public investment point a decade ago now typically have moved down toward 30 percent or less in public support, while other stakeholders have increased their share" (Lyall and Sell, 2006, p.8). According to SHEEO, from 2002 to 2007, per pupil education appropriations decreased 7.7 percent ($7,341 to $6,773) (SHEEO, 2008, Table 5). In 2007, total state expenditures for higher education had risen to 10.5 percent, but there will almost certainly be financial repercussions for higher education of the 2008 economic downturn (www.nasbo.org/publications.php).

One question, if such trends in privatizing public higher education continue, is: what are the implications of attracting a larger set of new "bankers" who value risk taking, but who also demand return on investment in the short term? What would a new infusion of private capital into graduate education and research mean for the enterprise? Over the last thirty years, industrial sector funding of academic R&D grew faster than any other source (federal, state/local government, non-federal) (National Science

Board, 2006). Will such trends "commodify" the curriculum such that only programs with immediate market value equal to their cost will survive? Or rather, will a new enlightened private investor class emerge who opt to invest in the long-term, high risk and unpredictable human talent development that has been characteristic of the U.S. government's investments in the past?

One can imagine two very different possible futures for the U.S. It may be that as global markets put even greater pressure on the innovation capacity of the U.S., business leaders will lobby even more aggressively to increase public investment in our universities as the source of the innovators and thought leaders of tomorrow. In this scenario, through some combination of public investment and private partnership, the infusion required for the U.S. to thrive may be forthcoming in 2020.

Alternatively, if such investment is not forthcoming, and since universities can survive a long time on past reputation, the decline may not be noticed until it is too late to recover. In such a scenario, the U.S. would fail to attract the most talented students from around the world, and even lose the top U.S. talent, because the academic programs, the faculty, and the quality of the laboratories have slowly eroded away. The U.S. in 2020 might still maintain a few stellar private institutions that are supported entirely by endowments, but they would simply not be adequate to educate the vast majority (70 percent) of doctoral students who were 15 years earlier trained in the great U.S. public research universities. At this point, it is not clear which of the two outcomes is most likely.

D. The acceleration of global competition

American graduate education is part of a global community in ways that go beyond the competition for international talent. From Brussels to Bangalore, and Beijing to Boston, conversations reflect common themes as universities plan to prepare the scholars and researchers of tomorrow. Among the themes that resonate in conversations across the globe: access and opportunity, quality assessment, mentoring, preparing a high tech workforce, interdisciplinarity, inadequacy of financial support for students, and competition from abroad.[3] While it is certainly true that the U.S. has been looked to in the last 50 years as the leader internationally in graduate education, it is also true that many sectors of the world are moving thoughtfully and rapidly to close the gap, and as they do so they are encountering many of the issues that dominate the graduate education landscape of the U.S. In some instances, U.S. graduate reform initiatives are being imported, replicated, and modified to meet other countries' national or regional needs (Stewart, 2005).

The current debate in the U.S. seems concentrated on whether or not we really face strong competition from abroad. Some take the position that in fact the alarm being raised by American universities and the corporate world is really a kind of hype designed to simply increase support for funding the university research and training establishment. Critics cite the outcry in the early 1990s of impending shortages of faculty in certain fields that never materialized.

Others question why increasing demand has not forced up wages for scientists and wonder whether the call for increasing talent production is simply a mechanism to keep wages down by increasing supply. The argument is typically framed in terms of whether or not there is a shortage of particular types of scientists and engineers. Changes (including "inevitable surprises" and emerging "unknown domains") in technology and U.S. market forces will likely require a greater number of new types of professionals to meet future workforce needs that will be very different than they were in the past. In some cases this may mean that, in the absence of future-looking policies, we are currently oversupplying a cadre of professionals for the jobs of the past (Lohr, Vanselow, and Detmer eds., 1996). But at the same time and for the same reason, it is also likely that we are undersupplying professionals to meet the workforce needs of the future.

However the current debates about relative shortages or surpluses impact the U.S. in the near term, there is general agreement that human talent development is the key to success for all countries in the future, and major countries and regions of the world are acting on that assumption to develop local talent and to recruit talent globally. By 2020 the "Bologna Process" in Europe will result in the integration and harmonization of higher education degree structures across old and new Europe. As Asian economies grow, their global demand for talent will far exceed the current supply or their educational capacity to supply that demand in the near future. China is rapidly expanding both its research centers and its graduate program enrollment, with the goal of doubling graduate enrollment in the next decade (Mills, 2006). One implication of the projected demand for talent and the global recognition of the importance of graduate education is that those educational systems that are best positioned to embrace international students and to prepare them for international careers in research will thrive. The U.S. is a current leader in this area, but others are now building capacity more quickly. Australia, for example, is anticipating that its current supply of international students (1.8 million in 2008) will grow to eight million by 2025 (Australian Government, 2005).

That the landscape for graduate study will be more competitive in 2020 is certain. What is less clear is whether it will be a relatively "spiky" or a relatively "flat" landscape. For Richard Friedman, technological advances, lowered trade protection, and political barriers have already resulted in a flat world in which there are almost no geographical barriers to the production of capital, thriving business, and the free flow of talent (Friedman, 2005). According to Richard Florida, however, the world is not flat but spiky, and the geography of major urban hubs, clusters of innovation, will continue to provide the key constraints on economic growth through science and innovation (Florida, 2005). In the flat scenario, graduate education in 2020 would function in a more broad-based landscape where technology and other factors lead to a wider distribution of both talent and talent developers. In the spiky scenario, Europe, the U.S., South Asia, and China will be the dominant players in the economy, and graduate education would be shaped accordingly.

E. Technology

There is every reason to believe that technology will influence the content and mode of delivery and thus may well influence as well the extent to which 2020 will be a spiky world of few or flat world of many major players in the graduate education enterprise. Technology is increasingly a central component of discussions of the changing graduate curriculum and modes of graduate instruction. The Sloan Foundation has conducted some of the most significant research on the subject. A recent report, 'Growing by Degrees' (Allen et al. 2005), documents the considerable growth in the number of students enrolled in programs with an on-line component—increasing 43 percent between 2002 and 2004. More than 40 percent of institutions (nearly two-thirds of research/doctoral institutions) offering master's degrees also offer some of these programs on-line. Penetration of on-line instruction is weaker at the doctoral-level where approximately 16 percent of doctoral programs offered in person are also offered on-line.

On-line or distance education has the potential to greatly reduce costs while increasing access and opportunities. Asynchronous delivery of instruction reduces the temporal dimension of course work and allows graduate students in geographically remote locations and facing severe time or personal constraints to pursue graduate study. An unanswered question is whether the promise of on-line graduate education, both in terms of cost and quality, will be realized. Large start-up costs and uncertain student demand have led to some frustrations in capitalizing on the well-publicized promise of distance education. For-profit institutions have been the most active in expanding on-line opportunities, raising a question of whether traditional universities can and will maintain their current portfolio of instruction or follow the lead of their for-profit colleagues.

Quality assurance, one of the central principles behind the historical successes of U.S. graduate education, also remains a concern for on-line instruction and is, as of yet, an under-researched dimension of distance education. Critical to maintaining quality will be conceptualizing ways to monitor on-line instruction, to promote sound mentorship of graduate students at a distance, and to promote research ethics. Not surprisingly, these are the same concerns of traditional delivery of graduate curriculum. If on-line instruction can generate significant student demand, it is imperative for graduate education to begin preparing the next generation of faculty scholars who will operate in this new domain.

Technology has already challenged graduate education to revise its expectations about the culminating products of graduate student work. The bound doctoral dissertation or master's thesis are now things of the past. The electronic dissertation and thesis (ETD) project is a major initiative of Pro Quest-UMI. In the future, graduate education must grapple with encouraging new outputs such as three-dimensional models, video footage, and non-linear research projects. It is likely that in the future these and other innovative forms of the presentation of research will come to dominate graduate education. Digital imaging and new publication formats will likely raise new ethical questions and make some old ethical challenges such as image manipulation and plagiarism more prevalent. At the same time libraries and future researchers will continue to require ready access to such materials, and libraries and graduate schools will need to grapple with new demands of the technological infrastructure required to promote the wide diffusion of knowledge.

Graduate education also will be challenged to respond to the ethical dimensions of new areas of technology, such as stem cell, genomics, nanotechnology, and climate research, where regulatory pressures may conflict with innovative research pursuits. Our policies and research activities on these fronts will not occur in a global vacuum, and other countries may well adopt policies that foster innovation in areas where U.S. researchers are constrained. It is quite likely that the regulatory environment for scientific research will play a larger role in countries' abilities to adjust their national competitive position in the global research economy.

F. Cooperation required for success

Many of the measures of research productivity (patents, publications) traditionally used as indices of national economic competitiveness may prove inadequate in an increasingly global research environment where traditional borders and boundaries are giving way to new collaborative and international networks. Even our conventional definitions of field, program, and institution, each as discrete entities, may be challenged by changes in the content of graduate education and the process through which it is delivered. Interdisciplinary research, for example, is often conceptualized in terms of the content knowledge it yields, while cooperation is thought of as a relatively independent context or process for pursuing knowledge in and between traditional fields. But we are increasingly coming to understand that, just as the fact of collaboration may shape the content of knowledge, interdisciplinarity is an independent variable that shapes the quality and process of graduate education.

The research of Barry Bozeman, for example, suggests that the social forces involved in knowledge creation may play a much greater role in motivating and shaping content and process than traditional, economic market-based incentives. The importance of social, organizational frameworks for the production of knowledge is important locally, through interdisciplinary collaborations, and globally, through joint and dual degree structures. Understanding that the problems and available talent of the future require greater time and investment in collaborative relationships may mean that institutions will need to devote more effort to thinking beyond traditional disciplines and traditional degree structures. The successes of collaborative interdisciplinary partnerships fostered by programs such as the National Science Foundation's Integrated Graduate Education and Research Traineeship (IGERT) program, and the Professional Science Master's program, between universities and private non-academic employers, may ultimately call for a reconceptualization of the ways in which we measure and evaluate research productivity, which may ultimately lead to new and innovative structures for the funding of research.[4]

G. Economic integration

As has been widely reported, the globalization of production is no longer viewed as a trend of the future. In fact, in addition to the so-called 'off-shoring' of many manufacturing jobs, the rapid globalization of service sector jobs is also a reality today. Economists contend that a significant portion of the productivity growth in U.S. manufacturing over the 1990s was driven by a second phase of 'service off-shoring' (Amiti and Wei, 2006). Given that manufacturing and service are now fully globalized sectors of the economy, one looming question for economists is not whether but when the final frontier, the research and innovation sector will be off-shored. The rapid growth of undergraduate and now graduate education in many developing countries, notably China and India, means that the same comparative advantage these countries now possess in low-skilled areas may in the near future be found in high-skilled areas. Rather than simply competing over manufacturing and service jobs in a global economy, the future competition will take place over knowledge jobs involving creativity, innovation, and scientific discovery.

The globalization of R&D will have dramatic effects on the U.S. economy, both positive and negative, but its impact on graduate education is an unknown. Such globalization could open new "markets" for U.S. graduate programs seeking to attract and recruit the next generation of the best and brightest students. If such globalization leads to the advancement of developing countries, new sending countries such as Turkey, Mexico, and Vietnam could emerge as traditional sender countries in Asia and India rapidly build their capacity to attract their own top talent. Turkey sent only 6,700 students to the U.S. in 1994, and just decade later has nearly doubled the number of students (12,474) coming to the U.S. to study. Recently, Vietnam has doubled and Mexico grown by 50 percent the number of students coming to the U.S. to study. These countries represent real opportunities offered by globalization and development.

From another perspective, this type of globalization might place wage and cost pressures on U.S. high-skilled workers, employers, and graduate schools. The traditional wages of home-grown scientists and engineers could diminish as lower-wage scientists and engineers abroad become more plentiful, and as lower-cost labs and facilities proliferate around the world. To remain globally competitive, U.S. graduate schools may have to respond in ways now familiar to U.S. businesses, compelled to focus more on cost savings, economies of scale, and return on investment. Universities may become increasingly reliant on electronic delivery technologies to expand their tuition base and increase marginal revenue to subsidize or replace traditional residential graduate programs. Additionally, pooling services, mergers, and outsourcing to reduce costs through economies of scale are some of the techniques that universities could borrow from the corporate experience with globalization.

What remains to be seen is how the various political and social contexts around the world will interact to accommodate or impede the globalization of innovation. It is possible that some of the conditions that characterize a democratic society may not be hindrances to a thriving manufacturing or service sector, but turn out to be crucial stumbling blocks for the emergence of a culture of innovation and scientific discovery. In the U.S., a robust graduate education, research, and science enterprise have emerged in the context of a complex set of interrelated factors such as: substantial governmental and private support, a sound legal infrastructure that promotes property rights, and the free and open exchange of ideas. The democratic underpinnings of national and university governance have likely played a large role in the story of U.S. international competitiveness in the second half of the twentieth century. These conditions, and the principles behind them, are not universally shared by all countries and regions who are now asserting their presence in the global R&D marketplace. Nor are these conditions and principles guaranteed to remain unchallenged or unchanged in the U.S., particularly under the influence of growing concerns about terrorism, espionage, and national security. The next decades may provide a test case both within the U.S. and in other countries about the extent to which there is a direct relationship between the conditions of democracy and a culture of research and innovation.

IV. Unknown Domains

A. Technological advances

Kurzweil's projection that by the year 2030 the merger between human and machine intelligence will be a reality may take several forms. One possibility that was once the domain of science fiction is that some of the hardware and software that we now carry as portable devices (iPods, blackberries, and cellphones) will be increasingly incorporated into our bodies. Medical devices and smart technologies to regulate various formerly natural processes, following the example of the pacemaker, will increasingly blur the line between technology and biology. These medical uses, as well as the leisure and cosmetic uses of such technologies, will raise important new ethical concerns and issues as well as new opportunities and challenges for graduate education.

New virtual equipment and virtual laboratory software (pioneered in medical education) may challenge our conventional notions about what aspects of graduate education require "hands on experience" in a physical laboratory environment, thus synergistically driving the appeal and efficacy of online distance education. One could imagine a world in which much of the work currently performed in the lab by Research Assistants is performed either by RA's in a virtual environment or by the software itself. Software may also free up curricular content in graduate education by absorbing some of the more mechanical and route thought processes. Stefan Wolfram's software program *Mathematica*, for example, can now instantaneously perform complex equations that once took mathematicians hours to perform. Just as common search engines can now make what was once an important mechanical aspect of nineteenth-century philology obsolete, *Mathematica* and similar programs can liberate scholars to focus on the more abstract and/or problematic aspects of a mathematical and scientific issue, and spend less time on "mechanical" labors that would otherwise be essential to the solution or definition of a problem. Kurzweil's "law of accelerating change" (whereby even "exponential growth is growing exponentially") in the area of artificial intelligence will have perhaps the most profound effects on graduate education in 2020. Not only will artificial intelligence impact curricular content and the daily cognitive activities of individual scholars, the technological absorption of formerly human cognitive tasks holds massive implications for redefining laboratory work and academic knowledge, potentially rendering some disciplines obsolete as it makes new ones possible.

Just as software may someday render the "Research Assistant" a relic of the past, technological innovation may radically redefine the "Teaching Assistant." In one such scenario, for example, curricular initiatives similar to MIT's "Open Course Ware" and "Open Knowledge" to make graduate curricular content and assignments available to the public for free, might generate a secondary, parasite industry of specialized teachers and tutors. Ultimately, a for-profit teaching industry could provide a cadre of outsourced "TA's," a natural extension of the for-profit online industry of writing tutors, exam coaches, and dissertation coaches that has already emerged. One role for the university in such a scenario could ultimately be to abdicate its social/teaching function and to become a pure research engine, to generate content, but not to oversee its transmission as knowledge. The long-running conflict between the research mission of the university and its teaching and faculty-preparation mission could be resolved, as it were, by "spinning off" the social responsibilities, with potentially serious consequences for quality and oversight.

The long-term results of such technological developments on research and talent productivity, and on the vitality of the disciplines, are truly unknown domains. Also unknown are what impact such developments might have on the quality and character of the relationships that are currently central to the graduate experience and that provide the scaffolding for the learning that ensues. Michael Schrage of the MIT Media Lab makes the point that, "When graduate students talk about the quality of their experience at a university, they tend to describe the quality of the relationship they have had." They loved of hated their advisor, they liked the camaraderie of conferences, etc. Research on graduate degree completion, for example, has shown that social integration is one of the most important factors contributing to students' tendencies to complete their degree, and the feeling of isolation is one of the main factors contributing to graduate degree attrition; this is especially the case for underrepresented minority students. In the new technologically mediated world of 2020, it is critical to attend to these relationship issues and to understand how the needs they meet will be addressed through technology in these years.

B. Science: life expanding treatments.

In many ways, we have a system of education at the verge of incompatibility with the changing life span. Given the average lifespan today, it may be appropriate to focus college and graduate preparation at the early stages of life, lasting at the longest into an individual's early 30s. Such training may now prepare individuals for their career without considerable need for additional rigorous training later in life.

However, if scientific advances expand the average life span to 90 years or more, our existing system may not be effective. If an adult's productive/working life expands further into their 80s, 90s, and beyond, third and forth careers will be dependent on re-training and lifelong learning. The productivity of this population would be all the more important if the current fertility rate falls below replacement levels. Rather than marginal participants in the graduate enterprise, this newly productive and engaged older cohort of individuals may demand course-work and graduate programs oriented to their interests and needs. And the life and career experiences that the 60 year-old corporate lawyer or banker brings to doctoral study in a field will stretch the boundaries of current faculty talents and disciplinary configurations. One can imagine whole new domains and interdisciplinary characteristics emerging from this new and more expert learner.

C. Culture—belief systems—democracy

Is it possible that the rise of religious fundamentalisms (Islamic and/or Christian), or some other cultural transformation, will reverse the basic principles of the enlightenment that are at the foundation of graduate education as conducted in the west? A national Harris poll in 2005 revealed that "a majority of U.S. adults (54 percent) *do not* think human beings developed from earlier species, up from 46 percent in 1994" (http://www.harrisinteractive.com/harris_poll/index.asp?PID=581.) With increasing demands for public accountability in higher education, and increasingly vocal support of the position that, while many public universities are funded by American tax dollars, university faculties are unrepresentative of the beliefs of most Americans, is it possible to imagine the introduction of curricular content in our public institutions determined by belief as much as by knowledge? What form this or the more likely scenario of a stand-off on such an issue would take is an unknown domain.

It is possible that so-called "western values" will permeate university governance and graduate education systems abroad even if those universities are located in countries whose political systems do not share those values. One perspective is expressed in Erik Peterson's statement that: "Four of the top five countries sending students to the U.S. are in Northeast Asia, and their next generation will experience unprecedented exposure to western values" (Peterson, 2005); but whether the relationship between academic and political belief systems will be one of mutual support or constant tension remains to be seen.

This debate is focused now on certain countries that are making substantial investments, yet at this point some of those countries lack the democratic institutions that Americans believe essential to effective development of human talent. Can progress be made when there is an imbalance between economic globalization and political globalization? Recent analysis of the situation in China suggests the Chinese think they can accept economic globalization without explicit change in their political system. In fact the main features of the market economy seem to be working; the Chinese have taken a very pragmatic approach to doing what works in the economic sphere. But it appears that the leadership in China rejects the assumption that economic integration into the global economy will lead to the establishment of institutions of western democracy (Sidelsky, 2005). Whether and to what extent such belief systems place a cap on the effectiveness of a country's graduate education enterprise remains an unknown domain.

D. Global politics

The motivation for the American government's current international strategy is that all nations and all people will thrive in a world where the principles of democracy have the widest sway. Just as Thomas Friedman used the metaphorical device of a "flat world" to imagine a world where *economic* opportunities are no longer constrained by regional and national borders, one could imagine a scenario in which economic globalization, technological developments, and global policies that actively seek to promote democratic processes flatten the *political* world in which differences are now so pronounced across the globe.

On the other hand, if the post-Cold War era continues to be dominated by small-scale factional wars, failed states, and terrorism, we may be at the start of a new era of heightened military activity and security concerns. One possible scenario is that an escalating series of terrorist attacks and subsequent global instability causes a "fortress America" mentality around the world. Rather than witness the unfolding of globalization as a force of connectivity, we may find that the global force that comes to dominate is one of provincialization—with local definitions of national security trumping the long term requirement of openness to ideas and mobility of student and faculty. In this environment, maintaining the principles of 'open laboratories' and 'open research' would be one of graduate education's major challenges. What kind of graduate school would be necessary to respond to such transformational events?

Similarly, a foreseeable scenario is that in response to "American competitiveness," legislators adopt a policy not of greater openness and greater hospitality to the world's top talent but rather of closed doors that emphasizes "domestic students first." In this scenario, international students, who currently comprise 50 percent or more of many U.S. graduate STEM programs, are increasingly discouraged from coming to the U.S. to pursue fields identified as key competitiveness areas (e.g. STEM fields). "Deemed export" policies become stricter and more prolific, binding the hands of all but the most resource intensive institutions, and international students find it increasingly difficult to gain access to U.S. graduate degrees. What would the impact of such a short-sighted economic competitiveness scenario be on graduate institutions?

Conclusion

This essay began by describing the graduate dean as a "steward" of graduate education in sense of both the enforcer of rules and the scanner of the environment. The 2020 project is founded on the belief that the latter aspect of stewardship will play a significantly larger role in the future than it has in the past. But, as often noted, "the trouble with the future is that is usually arrives before we're ready for it."[5] So how are we to prepare our graduate deans and university leaders to be ready for the transformations that will come?

Thinking about the future of graduate education must begin by acknowledging that some things are knowable if we look in the right places, and some things are simply unknown and can't be anticipated, but must be watched. Activities in both domains are required. But thinking about the future doesn't imply that graduate leaders remain inert until the future is revealed to them. On the contrary, they must act now, albeit with limited knowledge, in an effort to position their institutions to meet and shape the future for graduate students and programs.

This essay introduces an effort by the Council of Graduate Schools to enlist experts in the broad categories that we identify above as both "knowable" if we just look, such as demographic trends, and "unknowable" in detail, but hugely important to the future of the enterprise globally, such as transformations in culture and belief systems. It is in probing the "knowable" and exploring the "unknowable" that we are most likely to build a cadre of academic leaders who will be able to ensure that the future is not just some place they are "going to" but rather a destination they are creating. The Graduate Education 2020 project essays are designed to provide deans with the conceptual tools to build that future.

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2 All website URL's retrieved on March 12, 2009.

3 *Global Perspectives on Graduate Education* (CGS 2008) includes proceedings, reflecting this wide range of topics, of a Strategic Leaders Summit on Graduate Education convened by CGS in Banff, Alberta, Canada in 2007.

4 On the NSF IGERT program, see http://www.igert.org/. On the Professional Science Master's program, see http://www.sciencemasters.com.

5. Attributed to Arnold H. Glasow.

Graduate Education and the Knowledge Economy

Anthony P. Carnevale[1]

The future of graduate education is both robust and contentious, mostly because of the increasing economic value of knowledge. It's a safe bet that in the knowledge economy graduate education will survive, prosper and grow but that it will continue to be haunted by core tensions: (1) the tension between meritocracy and opportunity in access to graduate education; (2) the tension between the global, nationalist, and local perspectives on graduate and professional education; and (3) the tension between the intrinsic value of learning and the value of knowledge as capital.

In the knowledge economy, postsecondary education, especially graduate and professional education, has become the principle arbiter of access to elite careers as well as a powerful marker for social stratification. At the same time the increasing economic value of graduate education as well as R&D also creates tensions between the intrinsic value of research and knowledge in the disciplines and professions and its value as economic capital. These tensions are inherent in modern societies because they reflect a conflict among equally cherished but theoretically incompatible ideals. As a result, these conflicts are bound to be resolved not by "either/or" kinds of choices but by an ordering of values in particular contexts.

The Contradictions between the Elitist Economic Role of Graduate and Professional Education and the Democratic Ideal of Equality among Citizens Will Continue to Cause Tension

The future of graduate education has become increasingly complicated by its connection to the grand bargain in the American social contract. That bargain, struck early on in the industrial era, was necessary to reconcile the conflicting values implicit in the institutions of democratic citizenship and economic markets. In their youth during the eighteenth and nineteenth centuries, the ideas that animated citizenship and markets grew together in the same British and European neighborhoods and were allied in their revolt against feudalism, but they were also natural antagonists.

In theory, democratic citizenship and markets are driven by irreconcilable ideas. Democratic citizenship presumes equality, and market economies are driven by the economic inequality necessary to motivate work effort, entrepreneurship and the inherently lopsided accumulation of wealth and investment capital. Historically education has been a basic tool, along with expansion in universal and targeted social services from the welfare state, in resolving the contradictions between democratic citizenship and market economies.

The seminal statement on the role of education and the welfare state[2] in the social contract between citizenship and markets was formulated in a speech by Alfred Marshall to the Cambridge Reform Club in 1873. Marshall squared the equality implicit in citizenship with the inequalities inherent in markets by arguing that markets would become the paymaster for a constant expansion in publicly funded education and social services. Market economies would generate taxable wealth necessary to fund enough publicly provided education and social services to guarantee citizens full membership in society, while preserving free markets and legitimizing the economic differences those markets always bring among citizens. "The question" he said, " is not whether all men will ultimately be equal—that they certainly will not—but whether progress may not go on steadily, if slowly, till, by occupation at least, every man is a gentleman" who values education and leisure more than the "mere increase in wages and material comfort."

It is important to note that when Alfred Marshall spoke of the power of education to reconcile citizenship and markets, he was referring to the kind of education that was associated with "leisure" and valued more than the "mere increase in wages and material comfort" Marshall was referring to the intrinsic value of learning for encouraging the populace to "steadily accept... the private and public duties of citizenship" He assumed that education would be a universal common experience rather than a class-, gender- and race-based sorting device for allocating economic opportunity that ran from pre-school through graduate and professional school. In Marshall's day people learned their occupations on the job, not in universities. He did not foresee that universities would confer market power and wealth through access to the most highly leveraged occupations and knowledge.

In 1949 T.H. Marshall, no relation to Alfred, updated the original concept in a speech commemorating Alfred Marshall's classic formulation of the Western social contract.[3] T.H. Marshall asserted that the equality implicit in citizenship implied "a modicum of economic welfare and security" sufficient "to share to the full in the social heritage and to live the life of a civilized being according to the standards prevailing in the society. He went on to explain that the institutions most closely connected with this notion of citizen equality "are the education system and the social services." T.H. Marshall's speech was seminal because it became the widely recognized summation of the argument for the massive expansion in both public education and the welfare state after WWII.

But the education solution developed flaws as a mediating force in the bargain between citizenship and markets between Alfred Marshall's speech in 1870 and T. H. Marshall's speech in 1949. In his 1949 speech Marshall ruminated over the fact that the role of education as a mediating force between citizenship and markets was increasingly compromised by the growing relationship between education and elite occupational preparation and the economic value of knowledge. Education made everyone equal as citizens but those with the most education were more equal than others.

His ambiguity on the subject is still with us. He begins by noting that industrial society "has been accused of regarding elementary education solely as a means of providing capitalist employers with more valuable workers, and higher education merely as an instrument to increase the power of the nation to compete with its industrial rivals." He continues, "As we all know education today is closely linked with occupation" and that "[t]hrough education in its relations with occupational structure, citizenship operates as an instrument of social stratification."

As Marshall noted, education was increasingly in cahoots with markets in exacerbating both economic and social inequality. It was becoming a double-edged sword. Education was a great leveler but it also encouraged social and economic stratification by creating a hierarchy of occupations that threatened to reproduce elites over the generations. T.H. Marshall's concern was prescient.

The relationship between education and occupational choice, earnings and social and personal power has grown in the postwar transition from the industrial to the postindustrial economy. The education and occupational connections have grown. Currently, for example, of the 1,399,542 bachelor's degrees conferred in 2004, only 42,106 were conferred in the liberal arts and sciences, general studies, and humanities. Most community college education and training is vocationally oriented. Virtually all graduate and professional education is specialized and focused on academic, government or private sector careers. Moreover, vocational, technical and professional education are organized increasingly into an hierarchy of status, wealth and power.

Of course, using education as the arbiter of wealth and power has the virtue of its connection to meritocracy and individual responsibility. On our side of the pond Thomas Jefferson warmed up to meritocracy. In 1813

Jefferson wrote to John Adams:

> I agree with you that there is a natural aristocracy among men. The grounds of this are virtue and talents ……The natural aristocracy I consider as the most precious gift of nature for the instruction, the trusts, and the government of society…….May we not even say that the form of government is the best which provides the most effectually for a pure selection of these natural aristoi into offices of governments?

John Adams wasn't having any:

> Your distinction between natural and artificial aristocracy does not appear to me founded … both artificial aristocracy, and monarchy, and civil, military, political and hierarchical despotism have all grown out of the natural aristocracy of virtue and talents. We, to be sure, are far remote from this. Many hundred years must roll away before we shall be corrupted.

Besides, as social science would prove in the 20th Century, the meritocratic basis of education was, at least in part, a social construct. Education is itself stratified by race and class, ultimately creating a hierarchy of educational inclusion that confers public and private power over others well beyond the corrective reach of the universal franchise. The seminal work of Eric Turkheimer and his team at the University of Virginia shows that for most low-income kids there is no relationship between innate abilities measured in childhood and aptitudes developed by the time they are old enough for college (Turkheimer, 2003). Conversely, Turkheimer and his team find that most of the difference in the developed aptitudes among college-age middle- and upper-income adolescents can be accounted for by measured differences in their innate abilities when they were children. And because formal education is front-loaded in the life cycle, "the ticket obtained on leaving school or college is for a life journey" (T.H. Marshall, 1987).[4]

The marriage of education and occupation has also encouraged and legitimized the shift in power from the public realm of the citizen to the personal one of the professional. Everyone still has one vote but the most educated managers and professionals carry a new kind of personal empowerment that comes with esoteric knowledge. An increasing share of workers are empowered on the job in the postindustrial service economy because performing service work is an inherently more self-directed activity than tending inflexible machines. But the most educated, especially professionals, are the most self-directed and direct others because of their position in the occupational and institutional hierarchy.

Collective rule remains but is accompanied by a new kind of self-rule and rule over others by occupation (Wiebe, 1995). Those who have access to the graduate professions and managerial power have become "more equal than others" in withstanding market pressures because they work in occupations and professions that governed themselves, at least to some extent. Professional control over entry into occupations creates labor market shelters and new spheres of power that were inaccessible to the common lot.

It is hardly news that college, graduate and professional education has been the preferred path to middle class status and upper middle class earnings in the U.S., especially the path through graduate education to the professions. What is news is that the strength of the relationship between education and social and economic status has increased dramatically, especially since the eighties. With the disappearance of the blue collar economy, college education became the only game in town and the big winners are those who make it all the way to graduate and professional school.

The dilemma between educational merit and equal educational opportunity is particularly acute in the United States. The American course since industrialization has been exceptional. The Europeans have relied more on the welfare state to reconcile citizenship and markets. We have always preferred education to the welfare state as a means for balancing the equality implicit in citizenship and the inequality implicit in markets. The welfare state advances in the U.S. but grudgingly.

In our individualistic culture, education is preferred over the welfare state as the arbiter of economic outcomes because, in theory, education allocates opportunity without surrendering individual responsibility and gives individuals enough economic autonomy to minimize public dependency. After all, we each have to do our homework and ace the tests that get us through the education pipeline and into good jobs. Using education to allocate opportunity also provides a third way between the high risks that come with doctrinaire market fundamentalism and the dependency that comes with an expanded welfare state. Consequently, access to education bears more and more of the political weight that comes with the nations founding commitment to equal opportunity and upward mobility.

In addition, more recently, global competition limits the ability of governments to provide for the general welfare through publicly funded social services, making education the default strategy for social inclusion. Governments can only afford to provide equality through the welfare state to the extent nations succeed in global economic competition. In a global economy it becomes more difficult to foster the equality of citizens through the public provision of services, educational guarantees, labor market regulation and the direct redistribution of income because it reduces global competitiveness. At some point government expansion of the welfare state crowds out private investment and government regulation reduces the flexibility of national economies in responding to global change beyond its direct control.

With baby boom retirement in Europe and America, the conventional wisdom is that the Europeans may need to cut back on their welfare state and the U.S. may be done growing its welfare state dramatically until after the baby boom passes. In this new "market state" the government relies more on national competitiveness and robust markets to create the wealth that can fund greater inclusion (Bobbitt, 2002). Public investment in R&D, infrastructure and education become preferable to direct and tax expenditures for public consumption.

As the welfare state runs out of gas, at least in the short term, globalization favors the alignment of education and R&D with competitiveness and job opportunities over an expansion in the welfare state. It also favors the general use of education as an economic asset, rather than a universal common experience at the root of democratic citizenship, as originally envisioned by Alfred Marshall. Market forces encourage strengthening the alignment of educational selectivity and key occupations, making it more difficult to use education, especially elite education, as a leveling force in market economies.

Because it sits at the pinnacle of the hierarchy that joins education and careers, graduate and professional education reflects the tension between educational merit and opportunity at its highest and most exquisite pitch. Yet it presents this tension at a point in the sorting along the education pipeline when it is too late to do much about it, a fact that insures that access and equity issues are here for the long haul in graduate and professional education with no easy solutions in sight.

But for all the growing complexity in balancing the equality of citizens and the inequality spawned by markets, education and the public safety net provided by the welfare state are still the answers. Moreover, diversity and intergenerational educational mobility at the top of the education heap, in graduate and professional schools, are still the best metrics for measuring our success in balancing the equality of citizens and the inequality inherent in markets. We still tend to agree with T.H. Marshalls' homely pragmatism in his closing remarks in his speech on "Citizenship and Social Class, where he said:

> The main features of the system are inevitable, and its advantages, far outweigh its incidental defects… Apparent inconsistencies are in fact a source of stability, achieved through a compromise which is not dictated by logic…[and] a human society can make a square meal out of a stew of paradox without getting indigestion – at least for quite a long time (Marshall, 1987).

Graduate and professional education contributes to the creation of a new class of global workers that heightens the conflict between local, national and global perspectives on its proper economic role.

The struggle between the local and national classes is an American historical narrative that began in the nineteenth century and is still with us today (Wiebe, 1995). Local labor markets dominated the pre-industrial agrarian and small town economy. Gradually the need for access to capital and the need for economic order in both capital and labor markets created a new national economic class starting with the banks and the railroads, and ending with MacDonald's and Starbucks. Banking and railroads began early as national industries; whole extractive industries like farming, mining, logging, oil and others became national in search of investment capital and as the national regulatory and R&D regimes matured.

The knowledge economy is not only post-industrial, it is also post-national. Globalization adds a new class of highly skilled global workers to the ongoing power struggle between the national and local economic interests. The elite cadre of graduate and professional workers who are globally connected come with different perspectives and interests than the local and nation-bound workforce. The "local class" tends to work in local labor markets and in small business or local industries. The "national class" is more mobile and tends to identify with national institutions and labor markets. The "global class" is not bound by place, although they tend to be urban. They include finance, communications, transportation, education R&D, tourism, the sciences and various slices of the professions and international business. The new international classes of workers have earnings, autonomy, hegemonic power and global perspectives that set them apart as a new elite, oftentimes with different economic and political interests than the locally-bound or nation-bound workforce. It includes the managerial and professional functions in sectors that dominated the industrial and extractive economies. Of course, educational institutions have different missions, and there is some correlation between institutional type (community college, liberal arts college, master's-focused university, research university) and the scale of the labor markets in which graduates pursue employment.

To an extent, graduate and professional workers are scattered across the local, national and global classes. They can still choose a local, national or global identity. For example, a country doctor in general practice may identify with local hospitals and a family practice and another doctor in an urban setting may identify with the medical research community, teaching hospitals and elite medical schools in a nation or worldwide. The local school superintendents work their way up from inside the local district. The nationals bounce from metro to metro and identify with their national associations. International educators may manage systems development in emerging markets like Brazil, Russia, India, or China or in the less developed nations in Africa.

In the 21st century, the new international class adds another layer of political, economic and cultural tension. The internationalist identifies with global capital, a new source of power that threatens both the local and national classes. It is increasingly difficult to escape the hegemonic power of the global professional in any line of work. The result is a new dimension to the politics of resentment between the local, national, and global classes.

In the United States, the jury is still out on globalization and the role of American higher education, especially selective higher education in global markets. One narrative under consideration is generally associated with economists and the business community. That narrative argues that the relationship between national citizenship and markets is still a win/win proposition as described by Alfred and later on T.H. Marshall. It asserts that global markets will be the new paymaster for democratic inclusion, expanding the economy in ways that provide more job opportunity for Americans, not less. Moreover, global markets will increase our ability to fund education and critical social services that will, in T.H. Marshall's words, "fund a modicum of economic welfare and security" sufficient "for all to share to the full in the social heritage and to live the life of a civilized being according to the standards prevailing in the society" (T.H. Marshall, 1987).

Speaking in 1949, T.H. Marshall was aware that education allocated access to knowledge-based occupations, resulting in economic stratification. He worried over the stratifying effects of education but concluded that the economic value of knowledge ultimately resulted in higher living standards and greater inclusion. He recognized that knowledge was inevitably embodied in people and technologies organized into occupations and industries. He also recognized the key role of education institutions in creating and embodying knowledge. While the industrial organization of knowledge created inequality based on knowledge, it was the responsibility of the government to provide education and social services to fund a "modicum of economic welfare and security" sufficient to insure inclusion for all citizens.

I suspect that both Alfred and T. H. Marshall would make the same argument today in the new global context. I bet they would argue that American higher education and American labor markets need to be open to global talent in the interest of expanding economic domestic growth at the heart of economic opportunity and full citizenship. They would favor growing the pie over hoarding existing educational and economic opportunities, because growing the economic pie is the only way to produce wealth for funding inclusion through education and other improvements in the general welfare of the citizenry.

Language and culture create barriers to entry in many high skilled occupations like domestic law and the humanities. But we add barriers to entry by making foreign students feel unwelcome and building high walls around our domestic labor markets in science, engineering and other fields that can benefit from global talent. Many of our elite institutions work around these barriers by taking their brands offshore, but with no American job on offer their appeal to students is limited as is their direct effect on American economic competitiveness.

Our ambiguity over the global role of selective college education, especially in graduate and professional education, wastes the American advantage in the global contest for talent. The local and nationalist biases in American culture inhibit our ability to capitalize on our two key advantages in the new global economy. Our principle advantage is that we have better wages, better working conditions and more infrastructure, that invariably makes the most skilled knowledge workers more wealthy and effective in the U.S. than they would be in other nations. A good engineer in India can be a better paid and more productive engineer in America. Our second advantage resides in the quality of our colleges and universities, especially in our most competitive institutions. If we want to maximize our advantages in the global competition for talent we need to offer both a quality education and access to our labor markets for the world's best and brightest. This is especially true in science, engineering and other arenas where language barriers are minimized and where the market incentives for foreign students are much more powerful than they are for talented American youth who can make lots more with an MBA than they can with a Ph.D.

Strategies to exploit our advantages need both an education and a jobs component. Ultimately the only way we can compete freely for global talent and provide more graduate and professional opportunities for Americans is to increase the numbers of highly skilled graduates and professional jobs on offer in the Untied States. There is little point in increasing the supply of talented workers unless we have jobs for them in the fields for which they are educated and trained. The human capital of engineers who drive cabs are not fully utilized. Increasing the supply and jobs for innovative talent won't suffice if we don't house and equip the new talent effectively. An entry level professional salary may not exceed $100,000 but the added cost of housing and equipping an employee doubles the cost. An experienced professional ends up costing $400,000 to $500,000, especially in technical fields.

In selective higher education, moving toward these more robust strategies will require a shift in perspective from the local and national to the global. We will also need to recognize that selective education is not just a way to allocate good jobs; it is also a way to create them. The notion that there are overall economic returns from knowledge, other than those that accrue to individuals who get the good jobs, is counterintuitive. Investments in college as well as graduate and professional schools tend to be biased toward private returns. The result is underinvestment in the broader economic returns from education that cannot be captured by individuals or by institutions in the short term.

Ultimately recognizing the value of knowledge as "patient capital" suggests the need for institutional aid as well as more R&D spending. But, as colleges increase their role in allocating good jobs, funding systems shift away from institutional aid towards individual student assistance. Broad institutional interests don't vote and politicians have learned to cut institutional aid and dial direct to the families and students who do with increased student aid. The current financing system under-invests in broad social and economic returns that ultimately drive the social contract between citizenship and markets.

The Tension between the Intrinsic and Extrinsic Value of Knowledge Will Continue to Haunt the Future of Graduate and Professional Education

Some of the barriers to the expansion of graduate and professional education as well as R&D come from the tension between the intrinsic value of knowledge and its commodity value. In a sense it is the struggle between the R and the D in R&D and the struggle between disciplinary values and managerial values. As the economic value of knowledge increases, market power invades academe, intruding on the power of the disciplines and professions in much the same way economic rationalization invaded the guilds in a previous era (Brint, 1994; Krause, 1999). The venue for much of the struggle goes on in the context of the dialogue on the role of the university. Eric Gould says it best in his book *The University in a Corporate Culture:*

> "It is precisely in the nature of knowledge as capital that the cultural contradictions of academe emerge. While corporate practices have the upper hand in running the university, the culture wars that exist in every institution remain a struggle between two major epistemes of academic power: *commodity knowledge,* that is knowledge that has a use for the world of work, professional and preprofessional training, policy development, inventions, and patents; and *symbolic knowledge*, knowledge that deals with value judgments, ethical, cultural, aesthetic, and philosophical argument, and speculative science" (Gould, 2003, p.102).

My own bias is that the dualism in the tension between postsecondary education and the economic value of learning tends to be overstated. What seems irreconcilable in theory is often workable in reality. The increasing value of knowledge as capital does effect power relations within the University and between the universities, government, and markets. But over the long term the struggle should be about shares in a growing pie, not about absolute decline in the non-commercial value of knowledge. Historically, over the long haul, the increase in the utilitarian value of knowledge has always been the catalyst in the long revolution in human capital development in which the extrinsic value of learning leverages resources that fund its intrinsic value. More science and math begets more Shakespeare.

While the role of education has certainly been complicated by the growing economic value of knowledge, economic markets in knowledge seem to beget wealth that increases the demand for general learning. The reason appears to be that learning is an innate human urge relentlessly pursued for meaning and pleasure as well as profit. So the increase in the extrinsic value of knowledge increases time and financial resources for affording the irresistible impulse to fund the intrinsic values of learning.

Moreover, over the long haul the commodification at the core of the growth in education should also be the engine of its democratization. Specific learning requirements for work eventually become general learning requirements in the education system. Manufacturing engineers started out as WWII vets with no college. New commercial technologies create a hierarchy of educational requirements from the professional to the technician and the technically savvy sales rep and manager. Increasing demand should extend the reach, if not the traditional forms, of graduate and professional education to an increasing share of the population.

In theory the commodification of graduate and professional education and training shouldn't dilute its quality. The learning goals in the disciplines and the more applied versions of occupational curricula overlap considerably, especially in the post-industrial knowledge economy. If "commodification" means investing in narrow occupational training in graduate curricula, it's just bad economics, because in the postindustrial service economy the economic value of general skills, abilities, values and interests in particular occupational clusters exceeds and is growing much faster than job specific competencies. General occupational competencies like problem solving and critical thinking are the patient capital in most occupations nowadays. They enable and leaven further learning in applied contexts.

The traditional status differences between the academic and applied are generally oversold. Moreover, there is no reason why general competencies can't be taught in applied contexts as well as in academic disciplines. In some cases and with some people applied learning formats are superior to academic learning. Academic learning usually occurs in a hierarchy of increasing abstraction, which is opaque to the generalist or the interdisciplinary needs of the problem solver. Consequently there should be lots of opportunities for cross fertilization between traditional graduate education and work-based curriculums.

Of course, as the economic value of graduate and professional education increases we will need to remember that education and research is about more than dollars and cents. Publicly funded R&D and graduate education should do more than provide new technology and foot soldiers for the American economy. Educators, especially public educators, have cultural and political missions to ensure that there is an educated citizenry that can continue to defend and promote our democratic ideals. Graduate and professional education is also a crucial anchor for the professions in their struggle to maintain their values and standards in a world increasingly driven by the narrow valuation of cost efficiency and direct earnings returns—the medical professions are the most obvious cases in point.

Ultimately, however, the economic role of graduate and professional education is central, especially in the United States. The inescapable reality is that ours is a society based on work. Hence, if graduate educators cannot fulfill their economic mission to help grow the economy and help youths and adults become successful workers, they also will fail in their cultural and political missions to create good neighbors, good citizens and lifelong learners. And increasing the economic relevance of education should, if done properly, extend educators' ability to empower Americans to do work on the world, rather than retreat from it.

What is the future of jobs that require graduate education?

There are only two honest answers to questions about the future: I don't know and it all depends. The future is not some predetermined state that waits to be discovered. We invent the future along the way. But we rarely get the chance to recreate the future from the ground up. Absent the wholesale destruction of graduate education as we know it, the trends that governed our choices in moving from the recent past to the present, are likely to be continue to set the boundaries for choices that will determine the shape of things to come in graduate education.

The pressures for change in graduate education in the recent past have centered on the co-evolution of education and the global knowledge economy. Those pressures will strengthen and accelerate over the foreseeable future.

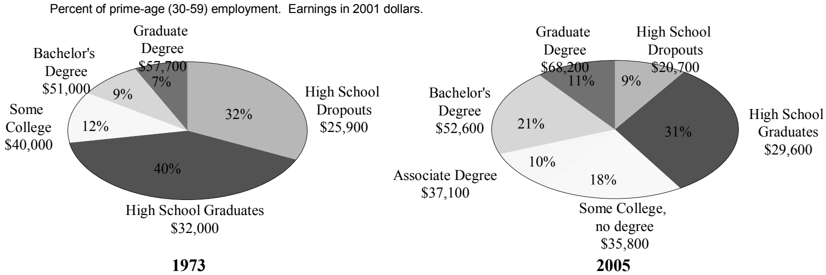
The engine at the heart of the co-evolution of graduate education and the economy is the shift from an industrial to a service-based postindustrial knowledge economy. Not surprisingly, in the knowledge economy graduate education is gradually becoming the new BA. In the sixties and seventies the BA guaranteed entry-level access to a broad array of industries and occupations. Nowadays the BA is not enough. The upward ratchet in educational requirements has made graduate education the best hedge against risk and the best bet for rewards in the labor market.

Graduate education grows because it is a knowledge-based function caught in the bow wave of growth in knowledge-based industries (see Figure 1). Job growth in graduate education is concentrated in high wage service functions, especially in white collar office jobs, education and healthcare jobs and technology-based jobs – the three legged stool in the knowledge economy that cover 54 percent of all jobs (see Figure 2). More than two thirds of the workers in these jobs have some kind of postsecondary education and the share with graduate education ranges between 11 percent and 26 percent, and with the exception of the hi-tech sector, all of graduate education is growing. Growth in low wage service jobs remains flat and factory jobs and natural resource jobs are in decline. Among these stagnant or declining job sectors only a third require any college and a meager 1 percent to 3 percent have graduate education.

Figure 1

Distribution of Education in Jobs, 1973 and 2001

Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



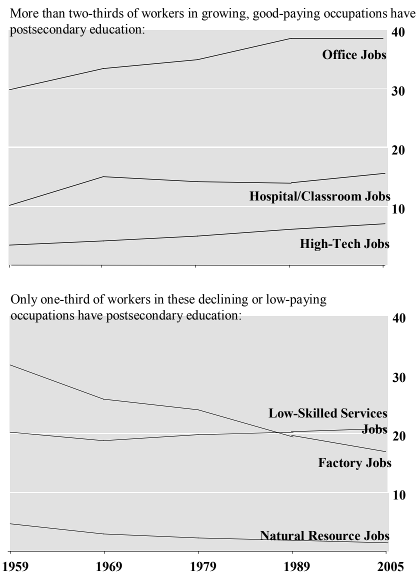
Source: Authors' analysis of Current Population Survey (March 1974 & 2005).

Figure 2

Employment and Education, 1959-2001

Percent of total employment

More than two-thirds of workers in growing, good-paying occupations have postsecondary education:



Source: Author's analysis of Current Population Survey (March 1970, 1980, 1990, & 2005) and Public Use Microdata Sample (1960 Census).

White Collar Office Jobs

The greatest increase in jobs and in the demand for graduate education has occurred in the nation's offices, whether situated downtown, on campuses, or in suburban office complexes (see Figure 2). While the share of graduate and professional degreed jobs in office functions (12 percent) is substantially below the shares in education and healthcare (26 percent) and hi-tech (17 percent), it remains the largest concentration of graduate and professional jobs because of the dominant size of the office sector in the economy (compare Figures 3, 4, and 5). Office jobs represent 39 percent of all jobs while education and healthcare include about 15 percent of all jobs and hi-tech jobs comprise about 7 percent of all jobs.

Those who hold white collar office jobs are the vanguard of the knowledge economy. They reflect the marriage of business services and intellectual property at the heart of the knowledge economy. They don't create technology or new knowledge in the disciplines, but they are empowered by flexible information and communications technology that allows them to make the most of technical capabilities, disciplinary knowledge and human capital organized in complex and flexible economic networks, more and more with global reach. Office jobs are high wage service workers in a world in which production has become a parlor trick and the greatest value added comes from service functions like information management, design, marketing, finance and new kinds of value added including quality, variety, customization, novelty, convenience and persistent innovation.

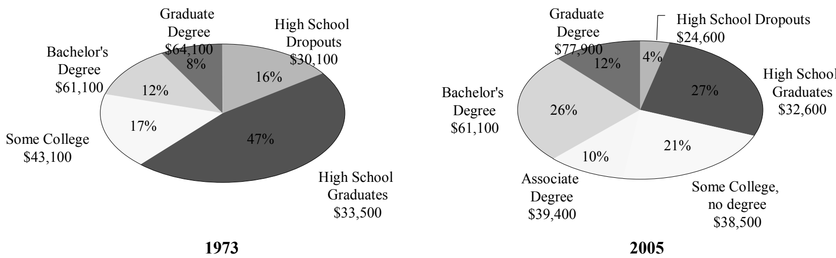
Office workers are increasingly hybrids with one foot in a knowledge discipline and another in a managerial domain. They are as close by as the Graduate Dean who negotiates the minefields between the disciplines and the entrepreneurial university. They include the chemists, biologists, and MD's in sales at Big Pharma as well as the lawyer with a science degree working on bio-tech patents and intellectual property rights. A substantial share are technically trained students who have pursued hybrid careers combing technical degrees with white collar organizational roles. The growth in demand for these mixed service and technical functions has suggested the need for interdisciplinary preparation that breaks down the silos between technical and white collar office functions.

Education and Health-Care Jobs

Not surprisingly, with awareness that the value of human capital is rising, more people are working in education and health care—jobs associated with the development and maintenance of human capital. The new economy requires more education, the demand for health care continues to rise, especially as the population ages, and because productivity is not rising as fast in these education and health-care jobs as it is in manufacturing. Because of increased demand and slow productivity growth, since 1959, health care has grown from 4 to 7 percent of all jobs. Over the same period and for similar reasons, education jobs have grown from 6 to 8 percent of all jobs.

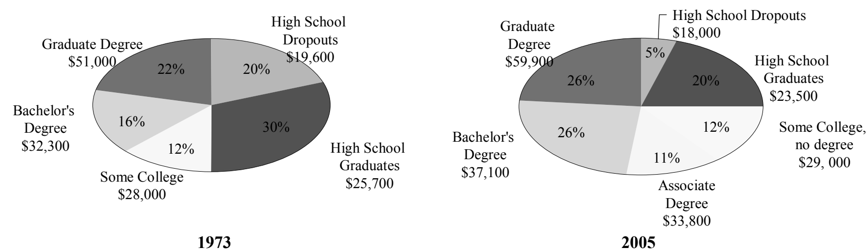
The health-care and education sectors have always been some of the most postsecondary education intensive in the economy. Even in 1973, one-half of workers in schools and health-care institutions had at least some higher education and 22 percent had graduate degrees (see Figure 4). Between 1973 and 2005 the share of office workers with graduate education increased from 8 percent to 12 percent (see Figure 3).

Figure 3
Distribution of Education in Office Jobs, 1973 and 2005
Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



Source: Authors' analysis of Current Population Survey (March 1974 & 2005).

Figure 4
Distribution of Education in Education and Health-Care Jobs, 1973 and 2005
Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



Source: Authors' analysis of Current Population Survey (March 1974 & 2005).

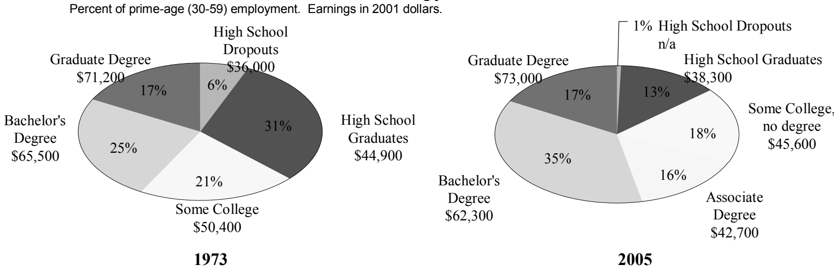
Technology Jobs

Since the late 1960s, the share of technology jobs has almost doubled, but technology jobs still only account for about 7 percent of all jobs in the economy (see Figure 2).[5] More and more people are using technology on the job, but it takes fewer workers to make, maintain, or repair it. Growing productivity endemic within technology sectors has held the overall number of jobs that require technical education to around 10 million, out of the total 141 million jobs in the U.S. economy. The technology sector eats and creates jobs simultaneously changing demands within the technical workforce—for instance, the shift from jobs from high-tech crafts workers to computer technicians— simultaneously creating a crazy quilt of surpluses in declining occupations as well as openings and worker shortages in growing occupations.

Figure 5

Distribution of Education in Technology Jobs, 1973 and 2005

Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



Note: n/a indicates the sample is too small to provide a reliable estimate.

Source: Authors' analysis of Current Population Survey (March 1974 & 2005).

By 2005, 86 percent of technology workers had postsecondary education, more than one-half had at least bachelor's degrees and 17 percent had graduate degrees (see Figure 5). Although the share of technology workers has doubled, the share of technology workers with graduate degrees remains unchanged in 2005, with the growth coming among technology workers with BA's.

The high but flat performance of graduate school workers in technology jobs stems directly from the unique nature of the technical job market. As you can see technology jobs pay well at every education level. As a result, the temptation to leave school and move into the job market prior to graduate training is more powerful than it is in other job arenas. In addition, learning on the job including technical learning is more powerful in technology jobs than in other areas because of technical change on the job. Oftentimes the best strategy in technical labor markets is to meet the minimum entry threshold for access in order to capture both the learning and earning on the front lines of technology change.

Technology jobs also exhibit a unique dynamic in relation to other job categories, encouraging hybrid education and career tracks. Technology jobs pay well right from the start but pay peaks early in careers. The way up in technology jobs is increasingly to move into other functions like sales, management, and finance. The hybrid career that combines knowledge in a technology domain with skills and other abilities in related functions like sales, management, finance, etc. is oftentimes a sound economic choice, especially in the short term. The hybrid option that combines technical knowledge with more service oriented occupations also affects education decisions. The combination of technical BA and an MBA or even a law degree can bring higher returns than a classic technical career track. Much of the growth in white collar office work includes technically proficient workers.

The emergence of the hybrid education and career tracks that combine technical and service learning is driven by the core dynamic in the knowledge economy. As knowledge increases in economic value the separation between research and learning in academic disciplines and applied learning dissolve in college and on the job. This is true in all disciplines but is most evident at the interface between technology and markets. The direct relationship between science and products and services has been obvious in chemicals and pharmaceuticals for a long time but has now become typical of other technical disciplines as well.

The hybridization of technical education and careers is probably here to stay, especially as the value of knowledge and the rate of increase in technical change continues to grow. The technical discipline has become part of a more complex value added chain that is much more heavily weighted toward the "D" in R&D. The prizes go to the disciplines but the money and societal impact go to those who turn knowledge into invention, design, production, financing, marketing distribution and sales and continuous innovations on the old idea that find new "value spaces" for a core technology. The value added chain begins in academic disciplines but is inherently interdisciplinary and requires transparency and alignment between the fragmented silos of academe and other institutions. The occupational competencies required not only mix a wide variety of knowledge domains but differing skills abilities, values and interests as well.

The future of technology careers for graduate-trained Americans is robust but complex. Current and projected demand is surely understated in the official statistics, in part because of the hybrid nature of demand for technical professionals. The supply of technical professionals is likely to be depressed by market incentives. The economic incentives are not universally robust for native born Americans with strong technical skills to pursue technical careers. Technical coursework is more time consuming and more difficult than better paid alternatives. A student with strong math and science test scores will make lots more money with an MBA than with a degree in chemistry. And combing the chemistry degree and the MBA may be the best bet but it is not the easiest way forward. Similarly a biologist will make half as much as an MD. The current flurry of programs to fund technical and scientific education may boost the supply of graduate level talent but to no avail if increases in funding for R&D and other demand side approaches don't increase jobs that require graduate education in technical and scientific occupations. To some extent supply creates its own demand but, in the main, supply side strategies are the sound of one hand clapping in labor markets.

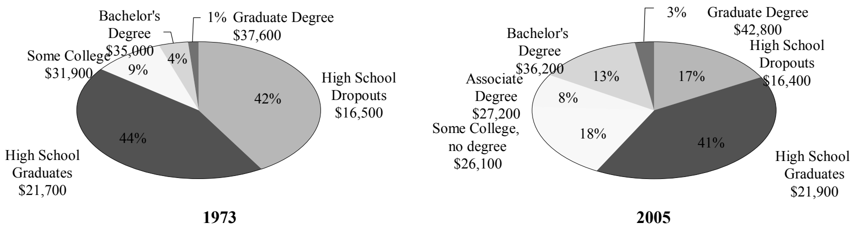
Globalization complicates the future scenarios. Given the structure of wage incentives in the U.S. and superior American wages, off-shoring, H1-b visa and internal transfers may be the market solution that gives American employers the best technical and scientific bang for their hiring bucks. But pirating other nations' top talent may only work for so long.

The overall global demand for technical and scientific education will certainly grow primarily to satisfy domestic demand in the BRIC nations (Brazil, Russia, India and China). My own very rough estimates show that it takes about 2 percent of our workforce to satisfy our need for technical and scientific talent educated at the graduate level. If that rough rule of thumb applies to the rest of the worlds' 6.6 billion citizens, then we are facing unprecedented shortages in graduate level technical and scientific talent for a very long time to come. Perhaps the optimum strategy would be for us to take on the role of the global graduate school in technology and science, cream skimming the best and the brightest for our own economy. But in spite of our historical educational advantages in the global contest for technical talent we are sending the message that foreigners are not welcome to study here and need not apply to work here.

Low-Wage Services Jobs

The share of low-wage services jobs has not grown since Eisenhower was president in the 1950s, remaining at about one-fifth of the available work opportunities (see Figure 2). Low-wage services jobs are a mixed bag (see Figure 6). For some, they are dead-end career jobs, but for many, they are transitional jobs that provide entry-level work that leads to further education or career mobility. The 13 percent and 3 percent of workers with BA's or graduate degrees in low wage service jobs are just passing through on their way to more education, better jobs or a full retirement. Most of these jobs are at the bottom of the new earnings and skill hierarchy. They include jobs for cashiers, retail clerks, stockers, cab drivers, cleaners, and other occupations that typically pay low wages and require low skills.

Figure 6
Distribution of Education in Low-Wage Services Jobs, 1973 and 2005
Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



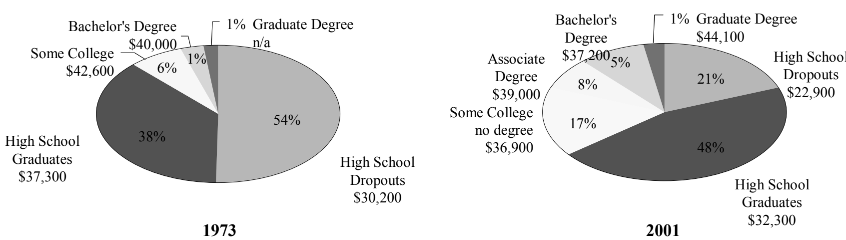
Source: Authors' analysis of Current Population Survey (March 1974 & 2002).

Factory Jobs

While low-wage services jobs are not growing as a proportion of all jobs, frontline factory jobs are shrinking both proportionally and in absolute numbers (see Figure 2). Between 1959 and 2001, the share of factory jobs fell from 32 to 17 percent of all jobs. That translates to 21 million fewer factory jobs in 2005 than would have existed had the 1959 share of employment continued.

In 1973, more than one-half of factory workers were high school dropouts and, by 2001, only about one in five had not completed high school (see Figure 7). In spite of the increase in college-educated workers in factory jobs, they are still a minority of frontline workers. In 1973, only 8 percent of workers on the factory floor had any college and, by 2001, that proportion had increased to more than 31 percent.[6]

Figure 7
Distribution of Education in Factory Jobs, 1973 and 2005
Percent of prime-age (30-59) employment. Earnings in 2001 dollars.



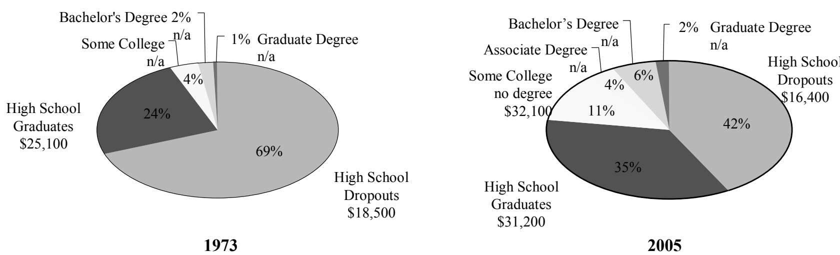
Note: n/a indicates the sample is too small to provide a reliable estimate.

Source: Authors' analysis of Current Population Survey (March 1974 & 2002).

Natural Resource Jobs

Like factory jobs, natural resource jobs, including farming, fishing, forestry, and mining, are in decline both as a share of the economy and actual jobs (see Figure 2). Natural resource jobs accounted for about 5 percent of all jobs in 1959. By 2001, these jobs had declined by more than two-thirds and only accounted for about 1.3 percent of all jobs in the economy. Workers with at least some college held 23 percent of natural resource jobs and a meager 2 percent had graduate training (see Figure 8).

Figure 8
Distribution of Education in Natural Resource Jobs, 1973 and 2005
Percent of prime-age (30-59) employment. Earnings in 2001 dollars.

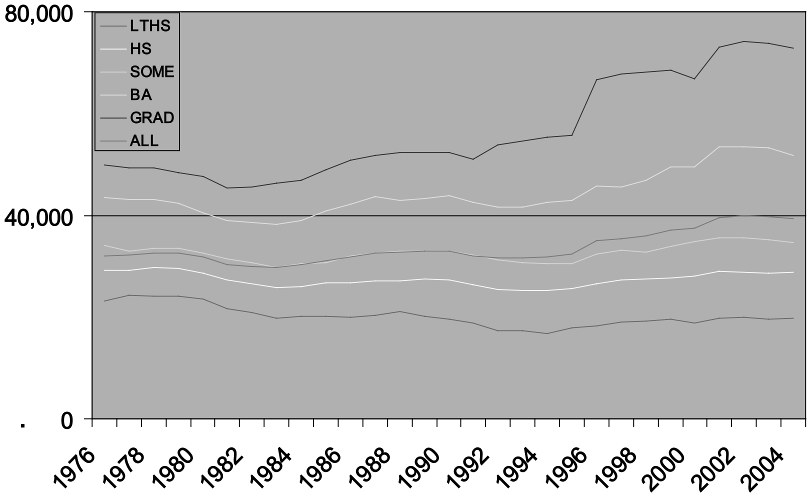


Note: n/a indicates the sample is too small to provide a reliable estimate.

Source: Authors' analysis of Current Population Survey (March 1974 & 2002).

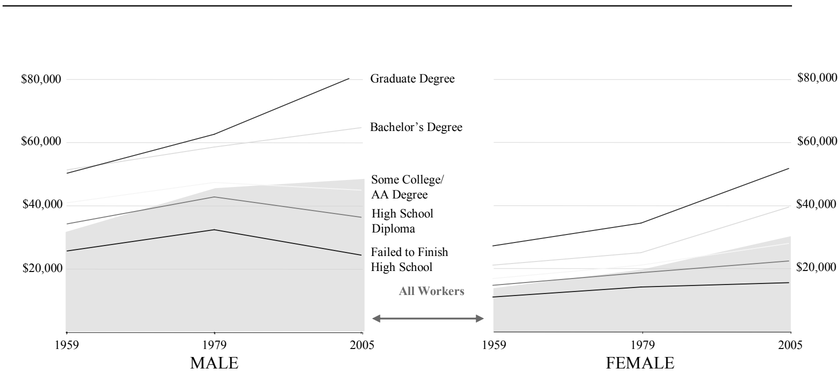
The increase in the wage premium for college, graduate and professionally educated workers, especially workers with graduate and professional degrees, relative to high school graduates is the most significant signal that the economy is demanding more knowledge workers (see Figure 9)**.** During the 1960s and 1970s, the dramatic increase in the number of baby-boom workers with at least some college and economic "stagflation" caused the postsecondary/high school wage premium to decline. By 1979, prime-age workers with at least some college that came with the baby boom and economic stagflation only earned about 43 percent more than high school graduates. But the declining wage premium eventually bottomed out, especially after the 1980 recession wrestled inflation out of the economy and allowed new investment growth. After the 1980 recession the restructuring of the economy from an industrial to a postindustrial knowledge economy accelerated dramatically. As a result, throughout the 1980s and 1990s, the wage premium for workers with postsecondary education skyrocketed, reaching 73 percent by 1999. The wage advantage of advanced degree holders was even higher, topping out at 124 percent.

Figure 9
The Growing Differences In Real Wages Have Been Driven by Access to College



Earnings advantages from college, graduate, and professional education have risen for both men and women but women's earnings are generally lower (see Figure 10). Women earn less than men at every level of education because they tend to have lower salaries in the same jobs and because they are concentrated in occupations and non-profit industries where earnings are lower.

Figure 10
Earnings Depend Increasingly on Educational Attainment
Earnings of prime-age (30-59) workers in 2001 dollars.



Source: Authors' analysis of Current Population Survey (March 1980 &2005) and Public Use Microdata Sample (1960 Census).

And wage advantages for college, graduate, and professional education have held up and improved in spite of a huge increase in the supply of college, graduate and professional workers. For example, just since 1992 we have added almost five million workers with graduate degrees into the employed labor force. Yet in spite of the dramatic increase in supply, the average earnings for all graduate workers have increased by roughly $20,000.

Since the eighties the middle class has been dispersing into two equal and opposing streams of upwardly mobile college-haves and downwardly mobile college-have-nots. For example, if we use the Current Population Survey (CPS) data to define middle class as the middle four income deciles, families making between $35,000 and $80,000 in 2004 real dollars per annum:

- In 1967 almost half of families headed by high school dropouts were in the middle class, with that number dropping to about 25 percent in 2004. Over the same period the share of middle class families headed by high school graduates fell from 70 percent to less than 50 percent. And virtually all of those families who left the middle class had fallen into the lowest three income deciles below $35,000.
- Between 1967 and 2003 the share of middle class families headed by workers with some college or an AA has fallen from 68 percent to 55 percent. Half of those who left the middle class have moved up and half have moved down below the $28,000, low-income threshold.
- Between 1967 and 2003 the share of middle class families headed by a person with a BA has fallen from 66 percent to 50 percent or sixteen percentage points. Of the sixteen percentage point decline, fifteen percentage points moved up into the top three family income deciles.
- Between 1967 and 2003 the share of middle class families headed by a parent with a graduate degree drops from 57 percent to 37 percent, a twenty percentage points decline but all those families move into the top three family income deciles.

Graduate Education Grows Because It Leverages Lifelong Learning, Career Choices and Earnings in Knowledge Jobs

As the above data show, the gold ring in the education and career merry-go-round is a graduate or professional degree. Graduate preparation signals knowledge, skills, abilities, values and interests appropriate to a particular domain. But graduate preparation is used as a proxy for more than competencies in particular theoretical and factual knowledge domains. Graduate preparation also signals the presence of general skills and developed abilities like problem solving and creativity, which enable further learning, adaptability, and innovation on the job. Employers presume that exposure to postgraduate preparation allows the employee to adapt and innovate on the job.

Labor markets reward the richest mix of general and applied learning with career choices and earnings. Those with graduate and professional education signal strong general competency because they have survived the K-16+ gauntlet. The graduate or professional degree signals deep knowledge in a particular domain. And the graduate or professional degree also signals mastery of the basic methods of inquiry and values that set the standards of evidence and the ethical boundaries on the responsible use of the power that comes with every branch of specialized knowledge. In addition the graduate or professional degree signals that the prospective hire probably has the key interests that motivate further development and innovation on the job in a particular occupation.

Essentially, graduate and professional education is valuable both for the learning it imparts and because it is the gateway to further learning on the job. Formal education and lifelong learning tend to be *sequential and complementary* in producing productivity and earnings over the long haul. A graduate education is often not required at entry in many occupations but it leavens all subsequent learning and brings higher pay off in performance, career choices and earnings later on in careers.

Academic preparation and learning on the job are sequential and cumulative, snowballing into increasing earnings advantages over a lifetime of working and learning. Youth with the strongest academic preparations have the greatest choice of employers and the careers that offer the most formal and informal learning on the job. They also have access to jobs that provide the surest access to ever more powerful and flexible technologies that maximize individual learning and productivity; technology that complements rather than substitutes for human capital—for example, the portable PC versus the keyboard with pictures of fries and hamburgers instead of numbers at a fast food restaurant. These advantages also accumulate across generations. Parents with the graduate and professional education have the highest earnings and pass educational advantages on to their children. In the short term more narrow forms of education or training can substitute for the broader competencies that graduate and professional education provides, but it does not provide longer-term adaptability, especially if narrow tasks are automated or shifted offshore.

The increase in demand for college, graduate, and professional workers results, in part, from the distinctive way labor markets for new educational graduates work in the U.S. When employers hire fresh out of school, they are often hiring strangers and therefore use academic qualifications (attainment, selectivity and concentrations in particular knowledge domains) as *signals* for *potential* job performance. The match between what is taught in school courses and real occupational knowledge, skill, ability, interests and values is imperfect. Schools tend to teach domain knowledge in academic formats but applied knowledge, skills, abilities, values and interests are critical to employers but harder to find in course catalogues or on transcripts. This is why usually employers aren't much interested in detailed educational transcripts. Depending on the occupation they are hiring, they tend to be interested in degree attainment, majors and selectivity of programs and schools. Once new school graduates are inside the labor market the employer focuses less on *potential* as measured by academic educational attainment, curricula, and selectivity and more on performance-based observed *competencies* in the workplace that are directly tied to applied occupational knowledge, skills, abilities, interests, and values.

When employers hire for potential they are essentially assessing an individual's potential as a learner and an innovator. As the knowledge economy takes hold in American workplaces the volume, speed, and value of learning on the job increases employer demand for educated workers because the most highly educated workers are likely to be the most effective learners in the new high performance work organizations typical of the knowledge economy. In addition, as the pace of economic change accelerates, employers are more interested in hiring proven learners and less interested in growing their own human capital by using long term employer/employee relationships.

The knowledge economy creates powerful synergies between postsecondary education, learning on the job and flexible technology—our own friend the computer in its various disguises. Employees with graduate and professional degrees receive the most formal and informal training from their employer. Training can increase employee productivity an additional by 3 to 11 percent per annum. And those who receive the most formal or informal training on the job are more productive and earn more than less educated workers who do not.

College educated workers are also more able take advantage of flexible information and communications technology on the job to increase their productivity and earnings. Workers with no postsecondary education tend to be hired into jobs equipped with technology that substitutes for skill—e.g. the cash register with the pictures of hamburgers and shakes on the keys in fast food outlets. Highly educated workers tend to be hired into jobs that give access to flexible technology that complements their skill – e.g. the personal computer. The difference is clear in the data. For example, according to analysis by Princeton economist Alan Krueger, workers with high school who use information technology on the job increase their productivity by about 15 percent but the productivity premium for those with graduate and professional degrees is nearly twice as high.

If anything the official data understates the importance of graduate and professional education because it only offers snapshots of current demand and ignores the constant increase in education requirements. For example, at any given point in time, most occupations have a variety of incumbents with different levels of education. But the clear trend in individual occupations is toward greater postsecondary requirements, with higher wages, especially among new hires, going to those with the most postsecondary education or training. Hence whatever the level of postsecondary requirements in an occupation today, it is likely to increase tomorrow.

There are a variety of other reasons why a static reading of the official data tends to understate postsecondary demand:

- First of all, all jobs are not equal. Jobs that require graduate and professional education are more likely to be career jobs, while jobs that require less education are more likely to be transitional jobs at the beginning or end of careers. Different kinds of jobs play different roles in different parts of the working life cycle. There are lots more neuroscientists who used to be dishwashers than dishwashers who used to be neuroscientists, but the static official data tends to treat the dishwashing and the neuroscience jobs equally.
- Second, a related problem is that the official data doesn't control for age effects which magnify the failure to distinguish between career jobs and transitional jobs. By including workers between 16 and 30 years old, the official data overstates the number of people who will actually end up in jobs that don't require postsecondary

education or training because many of these individuals may not have completed their postsecondary education or training until roughly age thirty. Similarly, including workers over fifty five, especially among men, adds jobs that are transitions from career jobs that required postsecondary learning into retirement.

- Third, jobs that require less education make up an artificially large share of job openings because they have much higher turnover than jobs that require graduate and professional education. As in the example above, there are more job openings for dishwashers than neuroscientists because dishwasher jobs turn over faster than brain surgeon jobs.

The most common understatement of demand for postsecondary education is an unintended consequence of the official government labor market data. The most commonly used government methods for measuring economic demand for postsecondary workers can grossly understate the importance of college, graduate and professional education in current and future labor markets. To some extent this is a classic bureaucratic fragmentation. Departments of Labor are interested in occupational data and Education Departments are interested in education data. The common interest in the relationships between education and labor markets falls between the cracks. The essential problem here is that the data systems we need fall between the institutional silos that house our statistical agencies in federal and state education and labor departments.

The principle method used by the U.S. Labor Department in assigning current educational requirements to occupations is based on choosing a predominant educational credential level among the various educational credentials characteristic of the occupational incumbents. The decision rule in deciding the predominant educational qualification is to set aside groups of incumbents in the occupation who represent less than 20 percent of total incumbents. For example, suppose occupation X includes

- 19 percent with professional degrees,
- 19 percent with graduate degrees,
- 21 percent with BA’s,
- 21 percent with some college or an AA degree
- And 20 percent with high school or less

Thus the 38 percent of incumbents in occupation X who had professional or graduate degrees would be set aside in determining the qualification for occupation X, even if professional and graduate degrees are growing faster than other credentials and the highest earnings in the occupation accrue to professional or graduate degrees. In this example Occupation X would be counted as one that required high school, some college or a BA at most.

Another set of problems that tend to underestimate the demand for college, graduate and professional education arises in projecting occupations and educational requirements. The U.S. Bureau of Labor Statistics projects occupational growth but holds education constant in its projections. Naturally, when education credentials are held constant, they don't grow very much. Hence if 21 percent of occupational incumbents had BA's in the base year, they assume that 21 percent will have BA's ten years later. Consequently, growth in postsecondary requirements using official data only reflects occupational shifts and ignores increases in postsecondary requirements that occur within occupational categories. This does allow for some growth in educational requirements. For example, healthcare occupations are growing faster than manufacturing occupations and healthcare occupations tend to carry higher levels of postsecondary credentials.

If used without proper adjustments the BLS methods can lead to gross understatement of both current future postsecondary education requirements in labor markets. Unfortunately, these errors cascade down through the official state and local data because all states and local authorities use the BLS model, and none of them, as far as I know, correct for education growth in occupational requirements.

If properly adjusted, however, the official data shows robust growth in demand for college, graduate and professional education. Notwithstanding the ups and downs of economic cycles, postsecondary demand and wage premiums have been growing rapidly since the eighties and if the past is any guide, the future promises more of the same.

The reader can see this in Table 1 below. The data shows the increase in college, graduate and professional jobs using:

(a) The actual distribution of education in jobs in 2002;

(b) The official occupational projections released by the federal Bureau of Labor Statistics; and

(c) Projections done for the U.S. Senate by Strohl and Carnevale that include an estimate of occupational upskilling in the projections model (Carnevale, 2008). We base our projection of postsecondary upskilling on a relatively simple and conservative regression model based on an analysis of actual changes in postsecondary attainment by occupation and industry between 1992 and 2004.

Table 1
Current and Projected Jobs by Educational Attainment

	a. Actual Jobs in 2002	b. Official Projection for 2012 Holding Education Attainment Constant By Occupation	c. Projections To 2012 Based On Historical Trend Increase in Education Requirements
Less Than High School Jobs	16,482,666	18,069,367	12,068,287
High School Jobs	44,698,388	51,612,592	50,256,976
Some College Jobs	27,559,941	30,187,249	28,930,825
AA Jobs	12,327,598	16,912,134	15,044,029
BA Jobs	26,406,079	33,295,247	36,204,861
Graduate and Professional Jobs	**12,809,023**	**15,225,880**	**22,979,341**
Total Civilian Jobs	140,286,000	165,302,000	165,483,000

The essential effects of our projections with upskilling added in is to increase the share of graduate and professional jobs from 12.8 million in 2002 to 22.9 million in 2012 – an increase of more than ten million jobs. By comparison, the official statistics suggest a much smaller increase from 12.8 million jobs in 2002 to 15.2 million jobs in 2012 – an increase of abut 2.4 million jobs. I wouldn't bet the farm on any of these projections but they do show the range in play and the need for more sophisticated public measures of education demand.

Will shortages of graduate and professional workers actually occur?

It all depends. Markets will adjust perhaps by reducing productivity or wealth and job creation below some optimal level or by finding substitutes for graduate and professional workers. Competition for postsecondary workers could increase wages enough to rapidly accelerate graduate and professional enrollment and persistence. But I don't think so. In the last thirty years we have consistently added graduate and professional workers but not enough to drive their wages down. Besides, we know that labor force growth is slowing to a trickle and degree production has been flat for a while with no signs of accelerating, especially given the demographic shift to low income youth and educationally disadvantaged minorities in our school age population. As the baby boom retires we will be trading highly educated baby boomers leaving labor markets for a less educated and skilled cadre of new entrants.

Automation will continue, but since the 1980's, automation has eliminated high school jobs and increased demand for college, graduate and professional workers. We could move toward skill-based immigration but the Congress is unlikely to allow any substantial increases over the current level of skill based visas. We could delay retirement for baby boomers. But political opposition would be significant, and the impact would be marginal. Delaying Social Security and Medicare, for example, will only delay retirement among low-skill low-wage workers who are dependent on public benefits.

A significant number of graduate and professional postsecondary jobs could be off-shored. Since 2000 almost 70 percent of jobs off-shored have been jobs that required at least some college, especially in technical functions. Anywhere from 6 to 15-million postsecondary jobs are theoretically vulnerable to off-shoring, but at present only 3-million postsecondary workers outside the U.S. have enough English-speaking skill to take American college jobs. Besides, in an economy that creates and destroys almost 10-million jobs a month, and will grow from 146-million jobs in 2007 to about 170-million jobs in 2014, the off-shoring threat is less intimidating than it seems at first blush.

Globalization is often treated as the wild card in the future of good jobs that require high levels of education but in most cases we overstate the threat of globalization to skilled labor in the U.S. The economic world is not really flat. Individual workers with graduate and professional degrees don't really compete head to head with individual workers with postsecondary degrees overseas. Economic competition does not occur between individuals facing each other on a flat surface. Economic competition tends to have the same kind of rough and irregular topography as the physical world. Economic activity occurs in geographic clusters of infrastructure and financial and human capital all bunched together—usually with postsecondary education and university R&D close to the geographic core of every growth cluster. This geographic clustering phenomenon is very persistent and distinctive locally, regionally, nationally and globally whether you map Starbucks or software production.

So long as we maintain and grow our human, financial and technological infrastructure we will benefit from global growth. The U.S. became the world's biggest economy when we surpassed China in the latter half of the nineteenth century. Eventually China will probably take back the lead. Ultimately the U.S. won't be the biggest economy but it will still be the richest with the highest demand for human capital. Currently the six largest economies are the U.S. first, then Japan, U.K., Germany, France and Italy. By 2050, for example, most agree that the new ranking in terms of overall GDP will likely be China first, then the U.S., India, Japan, Russia, Brazil, U.K., Germany, France, and Italy.

But even by 2050 the rankings in wealth per capita will very likely look pretty much the same as they do now:

Projected GDP and GDP Per Capita

NATIONAL RANKINGS BY TOTAL GDP 2007	NATIONAL RANKINGS BY TOTAL GDP 2050	RANKING BY GDP PER CAPITA 2050	PROJECED GDP PERCAPITA 2050
United States	China	United States	$84,000
Japan	United States	Japan	$67,000
United Kingdom	India	United Kingdom	$59,000
Germany	Japan	Germany	$51,000
France	Russia	France	$49,000
Italy	Brazil	Italy	$40,000
China	United Kingdom	Russia	$39,000
India	Germany	China	$32,000
Russia	France	Brazil	$26,592
Brazil	Italy	India	$17,000
Authors manipulation of data from the McKinsey Global Institute.			

Our panic over globalization is overstated for other reasons. The notion that our employers will continue to get their labor offshore or through immigration ignores the fact that nations like Brazil, Russia, India and China will need a lot more postsecondary workers if they are going to grow their own economies.

As illustrated by the example cited earlier, if it takes roughly 2 percent of our population with BA-level technical degrees to run different parts of the science and engineering infrastructure at the U.S. level of development, then our 6.6 billon person world arguably needs abut one hundred and fifty million of them and is currently at least 100 million scientific and engineering personnel short of what the world needs. . And what about college, graduate and professional personnel like school teachers, managers, architects and all the other college, graduate-level and professional workers required to keep a modern society going? So as you can see we are a long way from meeting the global demand for skilled labor and the demands of American employers are just a drop in the bucket. Our own increase in demand for educated labor is just a small benchmark in the long revolution in global human capital development.

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and as Chair of the National Commission on Employment Policy under President Bill Clinton.

2 In theory, public education is part of the welfare state but in practice, especially in the United States, it is separated by its connection to equal opportunity rather than the notion of equalizing outcomes associated with income transfers and other programs that intend to equalize outcomes.

3 The Marshalls were not speaking in a vacuum. They were offering liberal capitalism as an alternative to the collectivist ideas of their time. In Alfred's day that would have been the old feudal system as well as the Communists, Socialists, Anarchists and eventually the Fascists. In T.H.'s time, just after WWII, that would have been the Communists and Socialists. The current version of the argument has come full circle, back to the debate between liberal capitalism and a revived feudal theocracy.

4 This reality is one reason Americans resist the expansion of credentialing in labor markets. It is the source of the otherwise odd tension between employers and workers, who each have their reasons for wanting flexibility in hiring, and educators, who tend to favor professional credentialing.

5 Although there is much discussion about the importance of technology-based employment, it is rarely carefully defined. This document defines technology jobs to include only those jobs that are heavily science-based and/or utilize specialized machinery and equipment. These jobs either require at least a bachelor's degree (e.g., engineers, chemists, architects, computer system analysts, etc.) or some specialized postsecondary education or training (e.g., computer programmers, medical and other technicians, cad-cam operators, etc.). Virtually, all workers today have some contact with technology, especially information technology, but the definition of high-technology workers used in this paper limits their number to those with some special expertise, education, and training.

6 Many of the best-educated and highly paid factory workers hold technology-related jobs, and therefore, are included in the breakout for technology jobs.

Of course it's not your father's Oldsmobile – They don't make them any more

Stephen Joel Trachtenberg[1]

Long-range planning does not deal with future decisions, but with the future of present decisions.
-Peter Drucker

In the course of 30 years as a university president, I have often been invited to speak in public at forums away from my own campus and to write for various publications. The reasons for inviting me, I suspect, have not been uniform. On some occasions, my hosts were interested in my opinions about university governance. At other events or venues, I guess they may have thought that I would be amusing, inspire enough questions through crafty ambiguity to fill up a question-and-answer period, or to spark a mannerly debate with a slight, polite departure from the strictest academic norms. At still other times, I may have been invited because Robert Maynard Hutchins and Nathan M. Pusey were busy elsewhere.

I am absolutely sure, however, that your invitation to speak to the Council of Graduate Schools in December of 2007 and now to expand on what I said then is the first request that I understand beyond a suspicion or a guess. You made it clear to me that I, having just recently become an emeritus president, now have all my rights as a tenured professor and can express myself as I genuinely intend and want to, without fear of recrimination and without minding my manners. I am grateful to you for your understanding and for believing that I might have I wisdom to share beyond that offered by the late George Keller in his classic *Academic Strategy: The Management Revolution in American Higher Education* (1983) and by James Fisher and James Koch in *The Entrepreneurial College President* (2004).

I have been anticipating this new status with relish. While I have not been academically orthodox or absolutely correct during my presidencies—first at the University of Hartford for 11 years and then for 19 at The George Washington University—I have been aware that saying what I truly believe inevitably starts the engine of a grievance machine, lovingly oiled by colleagues, even if I have spoken off campus or published in an obscure journal with a small audience.

While I have a sense of bemusement now, I still believe it melancholy that any university president feels and responds to the same constraints that I felt for so many years. The academic and the lawyer in me see this as contrary to the Academy and the law, and I cite Justice Oliver Wendell Holmes for support. In 1919, he wrote:

> Persecution for the expression of opinions seems to me perfectly logical. If you have no doubt of your premises or your power and want a certain result with all your heart you naturally express your wishes in law and sweep away all opposition ... But when men have realized that time has upset many fighting faiths, they may come to believe, even more than they believe the very foundations of their own conduct, that the ultimate good desired is better reached by free trade in ideas... that the best test of truth is the power of the thought to get itself accepted in the competition of the market, and that truth is the only ground upon which their wishes safely can be carried out. That at any rate is the theory of our Constitution.[2]

If a university is to be open to the "marketplace of ideas," a term the Supreme Court first used in 1967 in a case concerning higher education,[3] then I wonder what good is served by limiting that marketplace by excluding the opinions, personal or institutional, of the institution's leader.

Yet this is manifestly the case. Why it should be, I am not sure, but I have long suspected that members of any university's extended family have a faulty understanding of the presidency. The president is not, as I have said many times before, the university made flesh, but so he is customarily perceived. Thus any speech that may seem uncomfortable to faculty or inconsistent with anyone's image of a particular university becomes a version of treason against the institution by the very symbol of the institution.[4]

No president is entitled to use his authority to browbeat or bend anyone to his personal beliefs or biases, but that is rarely ever the case. What faculties, especially, do not appear to understand is that one may lead, even love, an institution, yet find it in some ways wanting and express doubts or criticism in hopes of bringing about improvement. This is an obligation every president undertakes when accepting the job and quite obviously the opposite of institutional treason. I do not know if it is possible or even plausible to hope that the true nature of a presidency (and of individual presidents) can ever be understood on American campuses, but I do know how risky it can be to speak candidly. The results have been most baleful when I have wanted to discuss change, which is my subject today.

I hasten to warn you that any talk of change implies criticism of or at least incomplete satisfaction with the status quo; but such talk does not challenge the value of learning, research, or the pursuit of ideas. These define the university. Perhaps that is why it is so nerve-wracking for a university president to propose any kind of change, no matter how small, and only a little easier for a beloved former president. Change demands entrepreneurship and the taking of risks, so let me tell you I write with peace in my heart and honorable intentions — and of course with an eye on the First Amendment and the comforting knowledge that you cannot vote no confidence in me. Let me add a caution: the departures I will be suggesting are entrepreneurial and require taking risks by individuals and institutions.

My first thoughts are about what graduate education, especially at the doctoral level, must do prepare graduate students to be professors and, by implication, what I think most university graduate programs are not doing sufficiently. Considering how thick graduate-school course bulletins have grown and how busy graduate study and instruction are, to begin with what is missing may seem naïve or plain awkward. But it is no small accomplishment to notice what is not there and to derive some useful information from the discovery. Arthur Conan Doyle demonstrated this in "Silver Blaze" when Sherlock Holmes refers "to the curious incident of the dog in the night-time." "The dog did nothing in the night-time," complains Watson. "That was the curious incident." A real dog barks. Aside from enabling a student to master a discipline and earn a degree, a real graduate education needs to accomplish three things that it is not universally accomplishing now and the absence of which has gone largely unnoticed and, thus, without a remedy.

I will give pride of place to writing. Long ago I stopped being appalled and decided to settle for being dismayed at the inept writing of graduate students. Perhaps this should not surprise anyone who has been around the Academy for many years. It seems that mastery of an "academic style"—characterized, for example, by the passive voice and conclusions hedged in the conditional—is all that anyone expects of graduate students. Why not? It is what was expected of their professors who are passing on what they learned.

It is possible that their professors are also passing on what they in their own day as students failed to learn about writing. This distressing thought occurred to me several years ago when I received copies of some e-mails exchanged among faculty who were sitting on a university committee to consider how to improve the writing ability of undergraduates. Rather than cataloguing the faults and lapses of syntax and diction, I merely admit to being embarrassed that some of these professors had become tenured at George

Washington University during my presidency. I do not think it plausible that we can oblige tenured faculty to take a writing course; even safely emeritus, I cannot imagine bringing up that notion with the faculty senate. Perhaps the solution is to get writing instructors, i.e., a separate faculty, to work with our graduate students so that they will write well and be able, when the time comes, to teach their students something about writing.

Bad writing, I believe, is typically the product of bad thinking. Good writing is informed by many characteristics, including those that are hard to define, like style and tone. But good writing, especially expository prose, requires an intellectual command of logic and structure and a sense of concept, by which I mean no more than having a firm idea about what one wants to write. A lack of these intellectual qualities is what I mean when I refer to “bad thinking.” If that is the case, then perhaps we are admitting graduate students who belong somewhere else.

It is also true, however, that awkward or unclear writing arises from lack of training and attention. It may be a shame that we need to worry *in graduate schools* about so basic and important a skill as the ability to write serviceable English, but the sorry truth is that few colleges and even fewer high schools or primary schools are teaching writing. Graduate programs need to apply downward pressure on the colleges and schools to teach writing better, but while waiting for this—and we might as well be waiting for Godot—we would do well to require writing courses for our graduate students, even if we must hire a separate faculty to do so.

We also expect that many of our graduate students will proceed to be active and even prolific scholars who will write and publish articles and books. Certainly, it would be helpful if those publications were intelligible to an audience and ideally an audience beyond a handful of other scholars dedicated to a particular sub-discipline. More precisely, it would be helpful if their books and articles had a point and made the point in first-rate English. I suspect that many scholarly works are not clear, let alone compelling, because the thought behind them was never clear or compelling to the writers themselves.

The second thing that graduate education needs to do is to teach how to teach. Few programs do this with the urgency it deserves. I think there is more than one reason for this, and the first is an uncomfortable fact. Research universities believe that they are grooming scholars who may have to teach, but ultimately as little as possible. This is hardly the case, though many professors, with contrary and dispositive evidence before them, see themselves that way and routinely refer to “my work” when they mean research, not teaching. We know that most graduate students who earn a PhD in biology will not be conducting bench research funded by the National Institutes of Health, but teaching biology to undergraduates in a college. The same is true of students earning their degrees in the humanities and the social sciences.

Even those professors who achieve eminence and teach the lightest of loads will spend years earning their stripes, which means years teaching three or four courses a semester. Graduate programs—or rather the faculty and deans who educate graduate students—have to confront the reality that professors teach; perhaps we have failed to do so because we think more about the goals of the inanimate "program" than about the needs of incarnate students.

Another reason that we are not teaching how to teach is we do not seem to care about it a great deal. If we did, teaching assistants would be routinely supervised and instructed, even mentored. Typically, they are not, nor are young instructors. How many deans and senior faculty have any idea what their assistants, adjuncts, and junior colleagues are up to in the classroom? I am confident or hopeful, that on some campuses deans and faculty are paying attention, but it is not the rule. Our schools of education presumably know something about teaching, yet how many doctoral programs draw on their expertise?

When we do observe classroom teaching, it is usually in the year or so before a professor is up for tenure. That, it seems to me, is a little late—perhaps five or six years late. This indifference to teaching (and perhaps indifference is too a gentle word) does not serve junior faculty well and shortchanges our students. Our students are, however crass the term may sound to some ears, our customers. Most private universities are dependent on tuition which students or their parents or other benefactors pay for instruction. Teaching how to teach is not a luxury or an ornament: it should be as central a function of graduate education as is writing.

And so should be an understanding of university governance, my third point. Not to understand and to participate in university governance will have harmful consequences throughout the future academic careers of graduate students, as I will explain at some length.

Without invoking the management argument of the *Yeshiva* decision of 1980, it is a plain fact that faculty are involved in governing the university, especially in matters of curriculum and hiring colleagues.[5] Junior faculty do not usually know this, and many senior faculty do not either, perhaps because they never had real instruction in the subject. In the case of the younger professors, this may be understandable. They have been in school for many years, usually without a break. They are focused on their discipline and on acquiring the credentials necessary to get on in the discipline. They have not learned anything about the machinery of governance and may not know the machines exist.

The senior faculty, in my experience, are generally not much better. Some understand what is going on in their own departments, but rarely have a view of what makes the entire institution function. This may arise from a skewed professional outlook which David L. Kirp has aptly identified: "The most sought-after faculty regard their primary attachment as not to the school nor to their discipline but to themselves. For the favored few, every spring becomes a season of greed, as competing offers are weighed, not just in terms of salary but also in terms of research support, reduced teaching obligations, and the like."[6] We may add a certain loyalty to others in the same field whose approval faculty seek in order to move up the academic rock wall, but an attachment to the home institution is not universal among faculty at research universities, and thus it is not surprising that the governance and functioning of the university are unimportant or, just as bad, unknown.

Lack of awareness of university governance may also in part exist because small numbers of faculty tend to populate faculty senates. In 1988, when I arrived at George Washington University, I was welcomed by the senators. When I turned to the faculty in the autumn of 2007, I was greeted by the same senate leadership who had welcomed me 19 years earlier. Good people all and friends, but certainly 20 years in the senate is cruel and unusual.

If this machine of governance, the faculty senate, had term limits and were open to all faculty, *including those without tenure*, I imagine more faculty would understand how the university is governed—they would have to. But not having to know leads by default to an adversarial relationship, which is neither healthy nor profitable. I have found that the longer faculty sit on the senate, the more reactionary they grow, no matter how liberal their politics otherwise may be. They see themselves as the stewards of what exists, that is to say of the sacred, and consequently dismiss proposed changes often without inquiry.

This habit of mind is based on a misunderstanding. Many professors do not know how weak university presidencies and the administration are. Administrators can do some things on their own—among them, fundraising, creating chairs, and putting up buildings. But the curriculum, the course structure, and the academic calendar—to name just three critical parts of the machinery—require the participation and agreement of the faculty.

Faculty who do not do not understand this thus incline to think that the administration has some evil intent—our perfidy and venality are celebrated, after all—when it merely proposes a change or incline to resist any change that actually comes about (rara avis in terra), assuming it is something that will benefit the administration at the expense of the faculty. Instruction and participation in university governance could certainly change the faculty's outlook and maybe end the warfare-by-skirmish that poisons the atmosphere on so many campuses.

This is not academic politics that I am describing, but academic paralysis. It is evident to me that the structure of the university must change if universities are to survive financially. Using one example in the place of many, I will cite the university calendar. It is obsolete, using just little more than half the year. Yet revising the academic calendar to extend it from 28 weeks to 38 or 40 would enable any university to admit more students (thus raising more tuition revenue),[7] make more courses available to students when they need to take them, make fuller use of its physical plant, enable instructors to earn more money if they choose to work three terms instead of two, and still offer about three months of vacation every year. But this has happened infrequently. A notable example is Dartmouth which has a trimester divided into two terms of 14 weeks and one of 10, but is required only of students between their sophomore and junior years and not otherwise available.

While reforming the calendar is a matter of survival for universities and the province of university governance, I wonder how many of our graduate students understand this or would understand why I have written at length about governance and the faculty's role in it. Perhaps if we teach them that it is one way to secure their future employment and the future of graduate education, they will pay attention. But they have to be taught.

What I have written so far about instruction in writing, teaching, and university governance is the easy part. Of course that does not mean that I or any other president has managed to bring them off with complete success. The resistance to change is so stony and entrenched that it requires patience and persistence to overcome it. Or as Sun Tzu wrote, "To fight and conquer in all your battles is not supreme excellence. Supreme excellence consists in breaking the enemy's resistance without fighting." Difficult to bring off, but easy in conception since writing, teaching, and governance are matters of instruction in skills and the transfer of simple information. What I have in mind next is more difficult.

If we look back for 15 or 20 years, what will this tell us about graduate education over the next 15 or 20 years? We have seen upheavals in our lives and habits, notably because of globalization, immigration, the reallocation of resources—sometimes from the poor to the rich, at other times from the developed world to emerging economies[8]—innovations in vocations, new businesses with fresh demands on higher education, and the means to work and learn without regard to distance because of computers and networks.

This last point is a new phenomenon and in that way different from the others that precede it on my list. Globalization, for example, was called exploration, expansion, or empire in the past, and the movements of money and populations are part of ancient history. But if you can remember walking into an office around 1990, what would you remember *not* seeing? I think the answer would be a computer on every desk. It was only in the middle of the 1990s, when the internet—already about 30 years old—migrated from the engineering laboratories to everywhere on campus and off, that computers became ubiquitous. The phenomenon being so new, it is no wonder we do not fully appreciate it or understand it. But we will have to, and I will return to the subject later in this essay.

These many changes in technology, resources, and so on will not make graduate education in the classroom obsolete, but they will stress it and reshape it. The stress is there already, as you know. It is time to reshape graduate education, and especially doctoral degrees, to permit an entrepreneurial energy to inform institutions based on a mediaeval model—not to follow fashion, but to enhance our style.

An illustration from George Washington University. Several years ago, the University published a strategic plan. Under one of its rubrics, the plan required a critical inventory and evaluation of all of our PhD programs. We had 48; today the number is 36, and the final number, I suspect, will be lower still. Half a dozen of the PhD programs were and remain admirable and nationally recognized; these were clearly keepers. Others were obviously weak and attracting few students; these were easy to terminate because they added no value and had no constituencies. Still others were and are somewhere in between; what to do with them was and still is the most difficult question. The easy answer is to conduct some sort of analysis, keep those with promise, and bury those with none.

But the lines are never so completely clear. A single department may have both strengths and weaknesses. For example, to offer a PhD in English in every period requires a large staff to teach courses in and direct dissertations on everything from Beowulf and the Domesday Book to Robertson Davies and Robert Pinsky. Not many departments can provide such wide expertise—

or provide it in adequate quantities to a large number of graduate students.

But I have a proposition: If an English department is expert and ample in Shakespeare and Romanticism, offer a PhD in those areas. Chaucer and Donne and Saul Bellow may suffer, but less than the students who would otherwise be getting inadequate instruction and direction. What I am suggesting could be characterized—or satirized—as a "boutique" PhD program, but entrepreneurs in software, lobbying, and retailing realize that a niche can be more efficient than stocking the Sears catalogue with everything for everyone. Graduate schools and departments do not have to offer one-stop shopping. It is better that promising students enroll elsewhere than to disappoint or fail them; besides, for every student who does not find the ideal program at our university, another one is bound to. We should exploit our comparative advantages, as David Ricardo observed 200 years ago, rather than compete in every field.

We also need to ask ourselves if we are producing too many PhDs, especially in the traditional disciplines. It may be that some markets are saturated. Only 40 percent of students earning a PhD in English, for example, ever find a tenure-track job.[9] The rest are part of the peripatetic army of adjuncts or teaching at two-year colleges or employed elsewhere and otherwise. A less than four-in-ten success rate (surely success for someone who has earned a PhD is getting tenure, not being on the tenure track) is not worthy or even impressive, especially when it comes at such a high cost in time and money. Admissions to graduate programs should be connected with the best demographic information we can obtain on future needs, not on a belief that we can manage so many students each year and so we will admit them.

I am aware that paring down areas of study (the English PhD in Shakespeare but not in Chaucer) and limiting or reducing the number of students we take will seem unpleasant if not threatening to many in graduate education. I have little comfort to offer on this account. The American university is changing, admittedly more slowly than American and global societies, but it will have to accelerate its pace. Offering more options than we can fulfill and admitting more students than the market can bear are unsustainable and indefensible positions. The inevitable change may dose down programs, even whole departments in some cases, and make some faculty and administrators redundant. It may be even less comfort to refer to this possibility with the economist Joseph Schumpeter's phrase "creative destruction," but that is what will happen and has, to cite George Washington University's experience, already begun to happen. We should prepare for it as we look ahead and try to imagine ways in which faculty and administrators can continue, if only on a path that has shifted direction.

Beyond pruning PhD programs, we need to question whether we are offering the wrong kind of doctorates. Why should a student who intends to become a clinician or practitioner—for instance, a psychotherapist—need to get a PhD in psychology? The student who proposes to conduct research and teach needs the PhD because it is required to get a job. The would-be clinician does not. Of course the clinician-in-waiting no doubt wants to be called "Doctor" for reasons that are obvious. Some graduate schools have solved this particular problem by offering a degree called Psy D, a doctorate in psychology, but not a PhD. The program offers both the specific instruction the student wants and the title the practitioner will need—and a degree in less time and at lower cost.

Thus we have an academic doctorate—the PhD for the scholars and teachers—and what I will call a vocational doctorate for the practitioners and the clinicians; the scholars and the practitioners are certainly different species, and we customarily identify them by their professions, not by their degrees, so offering different degrees for different professions should not strike anyone as radical or far-fetched. If the word "vocational" seems beneath our academic dignity, I suggest we find another term or just swallow hard and get used to it. We have after all been giving vocational doctorates to our students for many years—we call them doctors and lawyers (and they are among the first we call for donations to the endowment). And if this can apply to psychotherapists, I see no reason that it cannot apply to economists and chemists, among others.

There are two reasons I propose this addition to our traditional roster of doctoral programs. The first is graduate schools must prepare students for the work they will actually wind up doing—and probably have already decided on—rather than the job we would like them to have. The better should never be the enemy of the good. Even many of those for whom the PhD seems the likely degree will not be working at top-tier research universities, but at masters level institutions or small liberal arts colleges where they will earn their bread by teaching. Would it not be more useful to prepare them for the work they will actually be doing? If we can offer a Psy D, why not an Eng D or a Hist D or a Bio D? We would also do well to reconsider the Doctor of Arts degree which was tried some years ago, but lapsed.

These might be called teaching rather than research degrees and would, I have no doubt, be seen initially as inferior by *doctores philosophiæ*, but I believe over time that bias would perish of its own weight and irrelevance.

After all, of the 3000 and more four-year colleges and universities in the United States, are there more than 100 or 200 that really qualify as research institutions whose professors are overwhelmingly engaged in research? Public or private, most live by and for teaching. We should produce *employable* teachers and practitioners.[10]

To continue with this idea, we can also ask how many people need doctorates of any kind. In many cases, it confers no more than status or a shift up the pecking order. In worse cases, a doctorate is a variation on grade inflation, assuming that all our students are above average and in truth reflecting a failure of undergraduate education to prepare students for the work they already have in mind. Reviving the Master of Philosophy as an honorable, final degree for those who want to teach or to practice accountancy or civil engineering should be more than enough, since it would be designed to prepare—or if you prefer, license—its holder to practice a profession, but not to profess scholarship or, for what it is worth, erudition. Masters in education and business are standard terminal degrees. At one time, an M. Phil in England was also such a degree in many fields, though no longer, and it has been little more than a fancy word for ABD in the United States. Granted: there is a question of optics at play. An M. Phil does not have the cachet or prestige of a doctorate.

That is true now, no doubt. But I do not think it can be true in the near future. The upheavals of globalization, transfer of information, and new professions that I referred to earlier are making it too difficult and costly to have students spend so much time earning their degrees, especially if they are concerned with collegiate and secondary teaching or aiming to be practitioners. This is also true for those who expect to be scholars, and that leads me to my second reason for departing from traditional thinking about graduate doctoral programs.

Some students will always want and be suited for a PhD. But we need to limit the number of years spent in earning one. It is too common to spend seven or eight years in this process, yet we produce lawyers in three years and physicians in four. By moving some students from academic degrees to vocational degrees which typically take half the time of a PhD, we will make more concentrated instruction available to the PhD candidates. This will save time. The PhD students also must learn that their dissertations are not going to win prizes and are not meant to. They need to demonstrate scholarly competence, not brilliance. This too will save time.

We need one more thing. We need to free graduate students from years of teaching to support themselves. Even more than questions of instruction or an eye on the prize, this adds years to a process that is much too long. Graduate study needs to be appropriately funded—and that, I think, is self-evident. This may seem expensive, but if we calculate how much more a graduate student would earn in *four* years in a real academic or clinical job after four years of not earning anything compared to what that student would earn over *eight* years as an instructor or teaching assistant, the former is a lot more. In other words, the social cost is less.

This does not mean that universities would lose their teaching assistants. Since I have suggested that graduate programs must teach their students how to teach, students would still have to give some time to the classroom—with supervision—but they would not have to do it so much and for so long that it would drag out the process of earning their degrees.

So far, I have suggested changes—or maybe tectonic disturbances—in two areas of graduate education, and both are easy enough to grasp in the mind if hard to wrestle with in the flesh. Adding instruction in writing, teaching, and university governance is, as I have said, simply addressing skills—that is to say, known quantities and familiar competencies in the Academy. Paring down the number of PhDs, restricting the range of them within a department, offering vocational doctorates parallel to the PhD, restoring scrupulously rigorous terminal masters degrees for some students, and enabling students to finish their degrees less slowly are matters of analysis and self-knowledge. Culturally and politically, they may be difficult to bring about, but we can understand them readily enough and, I hope, get on with the job.

The last problem I want to address, unlike those I have mentioned already, is harder to grasp and has a touch of melancholy about it. I will call it the problem of socializing graduate students and illustrate what I mean with a story from a friend, who cheerfully left—he says "escaped from"—academia many years ago.

When he was earning his ivy-league PhD, he thought he was being groomed—to the extent that anyone even paid attention to him[11]—to wear suede elbow patches, teach English at a place like Williams, and write fiction and witty verse on the side. His first job was at a state university in New England teaching freshman English. On a scale of one to 10 of culture shock, that was a 12. "For this," he asked, "I mastered half a dozen languages, aced my orals, and wrote a 300-page dissertation, not counting 80 pages of critical apparatus?"

His story is not unique or even surprising. But it is vexing. Our doctoral students are not socialized realistically—and by socialization I mean given preparation not just in their discipline but in the atmospherics of the Academy, in the terms of what the academic life is really like, and also, and perhaps most significantly, in the social skills necessary to succeed. My friend, an urbane and sophisticated man, characterizes himself in his 20s as an oaf. He had the surface sheen a good upbringing and a good education deliver, but no appreciation or sympathy for those who did not have what he had or who did not want what he thought he could impart to them.

This may be a series of his personal failings, but I find it convincing that the cloister of graduate school validated his oafish point of view and—this is what I find so sad—nurtured it and made it grow. Moreover, he was given, or allowed to develop on his own, ridiculously unrealistic expectations. There are not, and never were, all that many jobs at the Williams Colleges of the world, let alone in the Ivy League. Sadder still, no one counseled him that the number of teaching jobs was declining even though the number of graduate students was rising. This is not an out-of-date observation.

Had he done his work at a less prestigious university, the results would have been the same, I am sure, because we see the same results everywhere. Our doctoral students are routinely socialized for "the Academy," not for teaching language or anthropology or physics—that is, socialized for a notion rather than for reality. Yet comparatively few professors of any rank are teaching, or even conducting research, in the fields in which they specialized as students and in which they thought they would continue. It is no rarity for a Romance philologist to teach introductory Spanish, for an anthropologist of food to teach the large lecture course on anthropology's greatest hits, or for a student of quantum mechanics to teach first-year physics. It is hardly surprising to me that so many university faculty seem dissatisfied and unhappy. This may be—and I have a strong hunch that it is—because what they end up with is not what they had in mind when they went off to graduate school and earned their degrees, not what we trained and taught them to do and be.

This hunch was confirmed by the Carnegie Endowment for the Advancement of Teaching's *The Formation of Scholars: Rethinking Doctoral Education for the Twenty-First Century*, published last fall.[12] The report makes a compelling case that graduate schools in many disciplines have failed to define the goals of their programs, the purpose of qualifying tests, and the value produced by writing dissertations; moreover, while these issues are known, professors tend not to discuss them to avoid conflict. Thus students are trained and socialized as "scholars" according to an institution's particular (and often outdated) understanding of the term, but not as members of real faculties.

This, as I have already suggested, is a much harder problem to grasp than the others I have described. And the solution cannot be provided with formal instruction in basic skills or with structural change in the offering of degrees. Nor do I think there is a single formula since socialization flows from the culture—or maybe the drinking supply—of a given institution or even department, and they vary endlessly.

But I do propose that faculty and deans ask their students bluntly, and often, what they expect from an academic career. It will be instructive to learn what the students are thinking (or imagining) —and what they think is beneath their dignity or lower than their presumably high expectations. Perhaps being a university professor is not suitable for them. Better to learn that now than in 10 years when changing course will be much more difficult.

This is a tall order, but we have to figure out a way to fill it. Being realistic is not one of the more commonplace attributes of Homo sapiens, but I think it should be part of our job, if not part of our nature, to be realistic with our students and require them to look at their futures with their eyes open. That is the quickest route, I believe, to happy socialization.

Although I said this problem is perhaps harder for us to grasp than the others, we need to get our hands around all of them—because all of them cry out for change with equally loud voices. And while we all admit that change is difficult, it is equally clear to me that change is necessary. Graduate education is not, I repeat, going to become obsolete, but it very well may be growing obsolescent, wearing out and wearing out its welcome.

It need not. To this end, I want to offer an idea I consider provocative, but you may find provoking. I have pointed to problems in skills, doctoral program structures, and socialization. Where will we find their solutions? I imagine that our first instincts would be to convene panels of experts. These would include academic bureaucrats and consultants; being a bureaucrat and consultant myself, now with Korn/Ferry International working to identify the next generation of university presidents and deans, I have no objection. In other words, the usual suspects. And it would be *de rigueur*, i.e., comfortably daring, to invite experts on (1) the rise of graduate education in Europe and Asia and (2) distance learning.[13] I would add, more dangerously, (3) experts who earn their livings by imagining the future.

I do not mean to imply that academics and their regular consultants have nothing to say about the future of graduate education in America. Were that so, the enterprise would have collapsed years ago, and graduate education would have migrated elsewhere. Administrators and certainly deans of graduate schools are aware of the strengths of their institutions and the sometimes fearsome challenges staring them in the face. But outside counsel is more likely to be free of institutional bias and unconsciously received wisdom, or cultural artifacts, and conferring with those outside the castle walls can confer benefits. Thus my three categories of experts.

It is true that the preeminence in graduate education that we have enjoyed for many years is less than it used to be. This is not to say that our graduate students are migrating to Europe and Asia in large numbers, but it is clear that fewer graduate students from abroad or Americans see the United States as the *only* genuine option for advanced study. Problems with visas since September 11 have been vexing, but the worst of them are over, and consular foot-dragging is clearly not the sole reason for declining interest in graduate education among foreigners.

In a more positive way, we need an expert understanding of what has made graduate study in, for example, England and Ireland stronger and consequently more valuable (not merely more prestigious) to students who might have come here—or to Americans who might have studied here. It takes less time to earn degrees and the cost is less, but certainly time and money alone cannot explain their rise in recent years. We need to know more about their quality of instruction and of support, such as libraries and laboratories, and about organization and structure.

India provides some useful insights. The Indian Institutes of Technology (IIT) began with one campus in 1951 dedicated to teaching engineering to undergraduates. Today it has seven campuses (with three more planned) and almost as many graduate students as undergraduates. Moreover, IIT campuses may offer degrees in management, economics, and law, among others.

India's government has invested heavily in the IIT, but it has done something unusual for a public institution. The campuses are autonomous, thus some *may*, as I said, offer a law degree, but others do not; it is simply a question of demand in a particular region. It is also a different point of view about graduate study. The seven different campuses are not competing in every field with one another, but allocating resources to meet demand rather than attempting to create demand by offering more programs than each can sustain intellectually and financially.

This strategy reinforces my own belief that American graduate programs need to prune their offerings, respond more intelligently to the marketplace, and to seek collaboration rather than competition with other universities to avoid redundancy and control expenses. I do not pretend that these brief observations about foreign graduate study are exhaustive; I mean them only to be provocative and to suggest that American graduate education has no monopoly on good ideas and that experts, especially *from* Europe and Asia (as opposed to American experts *on* Europe and Asia), should be invited to speak at length at the hypothetical convention I have proposed.

For similar reasons, I want to invite experts on distance learning and computer technology, not exclusively from the Academy. It is only in the last 10 or 12 years that the internet has become an ordinary and expected part of the American university. Its possibilities, including distance learning and the virtual classroom, are still new, and their potential is not truly understood. By that I mean we do not yet grasp what parts of education we can deliver well online and what we cannot: learning and teaching online are not the same as shopping online.

It is clear enough that large lectures, for example, can be recorded; this idea was first proposed in a science fiction story I read shortly after the commercial introduction of videotape in 1956. The difference between now and 40 years ago is that the lectures can be delivered by Podcast at will and on demand, a great technological step, but not a substantive one, and substance is what we should be looking for. Can we deliver better instruction more efficiently and more usefully outside the lecture hall? If so, by what means and with what quality controls? I have heard, to cite just one technique, mixed reviews of threaded discussions, with some faculty finding them stimulating as preparation for seminars and others finding them no more than undisciplined gab-fests.

The same dissonance may be found today in graduate seminars, which suggests to me that technology, as I understand its use, is as susceptible to human foibles as the Socratic method and will not eradicate the human touch. But it would serve graduate education well to invite experts to analyze the present and imagine the future states of the internet for teaching.

And with this in mind, I come to my third—and most provocative—suggestion for my panel. I think it would add value to invite experts whose work is not academic, but practical, whose habits of mind are not operational, but focused on imagining future possibilities, and whose ideas are not guided by plans, but by opportunities and serendipity. As the writer James Richardson says, “The man who sticks by his plan will become what he *used* to want to be.”

I might stock my panel, for example, with science fiction writers,[14] representatives from the Defense Advanced Research Projects Agency, video-game designers, urban planners, communications theorists, hydrologists pondering future water shortages, and intelligence officers, among others.[15] Heterodox though these professions are, they have a common denominator: they are not bound or directed by tradition. To the contrary, they routinely seek to break away from it and feel free to improvise. Universities habitually invoke traditions and "evolution." Evolution is too slow a mode of change in a world where the rules and players are altered beyond recognition. I will not predict what my future-dreamers might suggest (unpredictability is the reason to include them), but I am sure they will not invoke evolution or tradition, a habit that has hobbled thinking on higher education.

Not long ago, John Sexton, the President of New York University, observed that there are "85 institutions in the world today that exist as they did 500 years ago," and 70 of them are universities. It is an interesting statement, John Sexton is a colleague, and I disagree with him. Universities have survived because they are different from what they were 500 years ago, unrecognizably different. The great mediæval universities typically offered instruction in about a dozen subjects; our graduate schools routinely offer courses in hundreds of fields, all but a few of them unimagined at Salerno and the Sorbonne. Had universities continued *to exist today as they did* 500 years ago with similarly narrow curricula, they would have been superseded by other institutions or survive on the solitary outskirts of society. Universities exist today because they have adapted. They must continue to adapt, but at a greater rate of speed. We need not jettison our traditions, but adjust them to be more enterprising and attuned to life as we live it today.

To put it differently, universities often say the equivalent of "This is not your father's Oldsmobile" as they make marginal adjustments, but keep producing Oldsmobiles, even when no one wants them. General Motors learned this the hard way. They launched the famous slogan in 1988—but continued to put Oldsmobile badges on carbon-copies of Pontiacs and Chevrolets that nobody bought—and had to cash in the Olds in 2004. Graduate education cannot afford to waste 16 years keeping alive traditions that want to die. It needs new blood, eyes, and ideas.

That is why I suggest inviting the video garners and the urban planners. Their value to us resides in their not being invested in the traditions of the university generally or of graduate education in particular. I am speaking for myself when I declare that, even if I brought about significant changes over 30 years of university presidency, I still cherished some sentimental attachments to the idea of higher education which quite possibly prejudiced my views and thus limited my scope. I may also be projecting my own feelings onto others, but I think we may share some of the same sentiment.

It is not easy for any of us in higher education to look *only* forward. Yet Peter Drucker is right, and we must look at ‘’the future of present decisions,” not their implications for the past or our traditions. We must understand the present decisions we make must be adaptable to circumstances that we cannot begin to imagine; even the future-minded experts I mentioned are not clairvoyant. Any decisions we reach about securing the future of American graduate education must be flexible and improvisational, less the 20-year plan than the 20-year imagination, lest we—or rather our successors in the Academy—wind up being "what we used to want to be." As soon as we codify both means and ends, we have guaranteed the former will not work, and we will never see the latter. We need to be open to revision and keep in mind that no good work is ever complete.

Some of what I have written here may not be welcome and the rest is daunting. No apology: I prefer to offer an overcast but helpful opinion than to remain silent or sunnily dismiss the problems as trivial and easily solved. Thus I am glad I have been able to deliver my news and provocation without fear of constraint, grievance, or an armed posse of my own deans. A year ago, I might have felt otherwise, so I thank you for your invitation and hope this essay is useful. The good news is that we are willing to examine and debate the problems graduate education must wrestle with and that we can, I believe, find the strength, will, and imagination to do so.

References

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2 Abrams v U S, 250 U.S. 616 (1919).

3 Keyishian v. Board of Regents, 385 U.S. 589, 605-606 (1967), Justice Brennan writing for the 5-4 majority.

4 The faculty reaction to the hostile introduction of Mahmoud Ahmadinejad by Lee Bollinger, president of Columbia, is a case in point. See nytimes.com2007/11/14/education//14columbia.html (November 14, 2007).

5 National Labor Relations Board v. Yeshiva University, 444 U.S. 672 (1980), Justice Powell writing for the 5-4 majority.

6 *Shakespeare, Einstein, and the Bottom Line* (Cambridge: Harvard UP, 2003), p. 62.

7 Yale, Princeton, and Stanford are planning to increase undergraduate enrollments by expanding their faculties, not their academic calendars. They are also among the richest universities in the world, and their means of expansion are beyond the means of all but a dozen or so institutions; moreover, their reasons for admitting more students are not financial, but questions of equity, also beyond the means of the rest of us who simply need additional revenue to stay even, let alone get ahead. See The Chronicle of Higher Education, November 23, 2007; chronicle.com/weekly/v54/i13/13aO230l.htm.

8 An example of the former is the brain drain of medical professionals from developing countries to the West and of the latter the introduction of medications from the developed world to poor countries.

9 See the Ms. Mentor Column in the Careers Section of The *Chronicle,* November 6,2007, which also puts the average time to earn an English PhD at 10 years; chronicle.com/jobs/news/2007/11/2007110601c/careers.htm.

10 The Center for Innovation and Research in Graduate Education at the University of Washington has said that doctoral education in the social sciences needs to undergo a "paradigm shift" to reflect the realities of the job market. See http://chronicle.com/daily/2007/11/848n.htm.

11 He taught Classics and American Studies as a graduate student and was recruited into the Classics program on the strength of having passed the equivalent of a first-year Latin quiz two years earlier. In three years of teaching, no professor ever visited one of his classes.

12 Published by Jossey-Bass and summarized in Inside Higher Ed on December 4,2007; www.insidehighered.com/news/2007/12/04/carnegie.

13 Other familiar experts could advise on the decline of the tenure track or the rise of "knowledge economy," among other topics, to good effect.

14 Ray Bradbury's Fahrenheit 451 (1953) predicted dystopia but also big-screen interactive video. Imagine that.

15 The actual composition is less significant than the willingness to listen to thinkers from outside the Academy. I owe this idea to a 1996 publication by the United States Air Force University called "Air Force 2025," an exercise in future planning. It is available online at www.fas.org/spp/military/docops/usa~2025/index.htmlI. avoid the term "futurist" because its meaning is too pliable to be valid.

The Role of Information and Communication Technologies in the Evolution of Graduate Education[1]

Chris Dede, Harvard University

A recent national panel on information technology and the future of the research university reached several conclusions (National Research Council, 2002), which include:

1. The extraordinary pace of information-technology evolution is likely not only to continue for the next several decades, but could well accelerate. It will erode, and in some cases obliterate, higher education's usual constraints of space and time. Institutional barriers will be reshaped and possibly transformed.
2. The impact of information technology on the research university will likely be profound, rapid, and discontinuous—just as it has been and will continue to be for our other social institutions (e.g., corporations and governments) and the economy.
3. Digital technology will not only transform the intellectual activities of the research university but will also change how the university is organized, financed, and governed. The technology could drive a convergence of higher education with IT-intensive sectors such as publishing, telecommunications, and entertainment, creating a global "knowledge and learning" industry.
4. Procrastination and inaction are dangerous courses for colleges and universities during a time of rapid technological change, although institutions will also need to avoid making hasty responses to current trends… (NRC, op. cit., p. 2).

The report further notes, "It is no great exaggeration to say that information technology is fundamentally changing the relationship between people and knowledge. Yet ironically, at the most knowledge-based entities of all—our colleges and universities—the pace of transformation has been relatively modest in key areas. Although research has in many ways been transformed by information technology, and it is increasingly used for student and faculty communications, other higher-education functions have remained more or less unchanged. Teaching, for example, largely continues to follow a classroom-centered, seat-based paradigm." (NRC, op. cit., pp. 5-6).

The purpose of this commissioned paper is to sketch the probable impact of information and communications technologies on the evolution of graduate research and education. Its intent is to stimulate you to make proactive, strategic decisions in your present to shape our future. This study begins not by describing advances in computers and telecommunications, but instead by articulating generic opportunities and challenges for graduate schools, because otherwise technology is a solution looking for a problem.

Challenges Driving the Evolution of Graduate Education

In the report, “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future” (National Academy of Sciences, 2006), sweeping changes to make graduate education more effective are seen as crucial to our nation’s ability to compete in the emerging, global, knowledge-based economy. Some of that report’s recommendations are targeted to improving instruction at every level of American education, ensuring that all students are taught in ways that encourage and enable realizing their intellectual talents. Other recommendations involve increased investment, such as 5000 new graduate fellowships per year in “areas of national need,” as well as a $500M fund for Advanced Research Instrumentation and Facilities. Yet, even if these recommendations for increased funding are implemented, resources for research and for improving graduate education are difficult to obtain, with intense competition for limited funding (Stimpson, 2004).

Also, our society’s priorities have shifted from basic, curiosity-driven scholarship to research that may have strong theoretical components, but is oriented to issues and problems related to the economy, the environment, and public policy (Stokes, 1997). As a result, graduates of PhD programs have experienced difficulty in finding employment conducting the basic research for which they were trained, and many employers report conventional doctoral education is so specialized that some graduates struggle to perform in entry-level jobs outside of academic and research settings (Abt Associates, 2006).

Recent studies about doctoral education have produced largely similar recommendations (National Academy of Sciences, 1995; Nerad & Cerny, 1999; Golde & Dore, 2001; Nyquist, 2002):

- increase the versatility, and therefore the career options, of doctoral candidates through training in skills commonly required in the private sector, through internships, and through increased career counseling;

- encourage interdisciplinary work and innovative, problem-focused research;
- inculcate values and ethics;
- foster fluency in technology; and
- incorporate understanding of the global economy and environment.

A number of major, national initiatives to improve graduate education have responded to such recommendations, including the Woodrow Wilson National Fellowship Foundation's Responsive PhD program, the National Science Foundation's Integrative Graduate Education and Research Traineeship (IGERT) program, and the Council of Graduate Schools' Preparing Future Faculty (PFF) program and Responsible Conduct of Research (RCR) initiatives.[2] What is the role of information and communication technologies in aiding graduate universities to overcome the various challenges facing research and education as we prepare to meet the needs of the knowledge-based economy? Answering this question requires forecasting the evolution of technology, of scholarship, and of teaching/learning.

Technology-driven Changes in Graduate Education and Research

Since 2002, a variety of high-level national reports about global competitiveness, U.S. economic development, and education have all expressed similar concerns about the need for dramatic educational enhancements (Committee for Economic Development, 2003; Federal Reserve Bank of Dallas, 2004; Organization for Economic Cooperation and Development, 2004; Business-Higher Education Forum, 2005; Business Roundtable, 2005; Task Force on the Future of American Innovation, 2005). Parallel to the "Rising Above the Gathering Storm" report discussed earlier, these calls to action highlight comparable, interrelated themes. They stress that U.S. schooling at every level, including graduate education, has not yet transformed to create the high-skills worker with creativity, proficiency in information and communication technology, and problem solving abilities necessary for the competitiveness of regions, states, and the nation in the new global economy (Dede, Korte, Nelson, Valdez, & Ward, 2005, pp. 2-3).

Such an educational transformation necessitates the sophisticated usage of information and communication technologies, since these are largely responsible for creating a "flat" world and knowledge-based economies generating the socioeconomic shifts detailed above (Friedman, 2005). In their book, “The New Division of Labor: How Computers are Creating the Next Job Market,” Levy and Murnane (2004) document how, as technology advances to take over routine cognitive and manual tasks once performed by the labor force: “Growing proportions of the nation’s labor force are engaged in jobs that emphasize expert thinking or complex communication—tasks that computers cannot do” (pp. 53–54). These economists go on to explain that “expert thinking” involves “effective pattern matching based on detailed knowledge, and metacognition, the set of skills used by the stumped expert to decide when to give up on one strategy, and what to try next” (p. 75). “Complex communication” requires “the exchange of vast amounts of verbal and nonverbal information. The information flow is constantly adjusted as the communication evolves unpredictably” (p. 94). Such expert thinking and complex communications at their highest level are the core of graduate education, and yet, for the most part, the optimal integration of these skills with skills in information and communication technology has not occurred in graduate degree programs. Nor have graduate curricula adapted to keep pace with advances in learning and in technology.

In recognition of the need for such educational reform, the National Research Council panel on information technology and the future of the research university (2002) called for several types of changes in teaching/learning. Universities should deemphasize lectures and the common reading list. Instead, educational experiences should utilize information and communication technologies to enable interactive, collaborative learning. Faculty should involve students in the co-creation of media-rich learning environments and should inspire, motivate, and manage an active learning process rather than communicate intellectual content directly. University education can improve by making learning available any place, any time through the simulation of physical phenomena, gaming technologies, and “telepresence” and “teleimmersion” (the ability of geographically dispersed sites to collaborate in real-time).

The NRC panel recommended that shifts in instruction parallel technology-based changes that have taken place in the nature of research processes, including new modeling tools, databases, and knowledge storage. In the latter area, for example, the panel posited that the university library is evolving from a collection house to a center for knowledge navigation, a facilitator for information retrieval and dissemination. Such transformations have important implications for instruction.

Technological Changes that Inspire Change in Instruction

> The use of information technology to simulate natural phenomena has created a fourth modality of research, on a par with observation, theory, and experimentation. Moreover, there is erosion in the conventional understanding that some types of research are more amenable to information-technology contributions than others; new database and modeling tools, for example, are unexpectedly changing fields that had previously made little use of computing power. New types of research organizations, such as "collaboratories" (far-flung networks of researchers and laboratories) are appearing that could not have existed without this new technology…
>
> Actually, some of the most powerful applications of information technology have already begun occurring in the humanities, social sciences, and the arts. Scholars now use digital libraries such as JSTOR (www.jstor.org) or ArtSTOR to access, search, and analyze complete collections of scholarly journals or works of art... Archeologists are developing virtual-reality simulations of remote sites and original materials, such as papyrus manuscripts, that can be accessed by colleagues throughout the world. Meanwhile, social scientists are using powerful software tools to analyze massive data sets of materials collected through interviews and field studies. And practitioners of the visual and performing arts are applying technologies that merge various media—fine art, music, dance, theatre, architecture—and exploit all the senses (visual, aural, tactile, even olfactory) to create new art forms and experiences (NRC, op. cit., pp. 30-31).

Over the next couple decades, how might technological trends in the areas of knowledge storage and modeling tools combine to transform the nature of research and education in graduate school? One thoughtful perspective on this issue has evolved through the National Science Foundation's emergent conception of "cyberinfrastructure" as a means of actualizing the promise of sophisticated information and communication technologies.

A Vision of Research "Cyberinfrastructure"

In recent years, the National Science Foundation has championed a vision of the future of research that centers on "cyberinfrastructure": the integration of computing, data and networks, digitally-enabled sensors, observatories and experimental facilities, and an interoperable suite of software and middleware services and tools (National Science Foundation Cyberinfrastructure Council, 2006). Gains in computational speed, high-bandwidth networking, software development, databases, visualization tools, and collaboration platforms are reshaping the practices of scholarship and beginning to transform teaching. Sophisticated simulation software and distributed, wireless observation-networks are enabling the exploration of phenomena that cannot be studied through conventional experimental methods. Computational models, such as those based on chaos theory, are dramatically extending the limited range of models available through mathematics alone. "Fewer and fewer researchers working at the frontiers of knowledge can carry out their work without cyberinfrastructure of one form or another" (NSF, op. cit., p.5).

To realize these potentials of cyberinfrastructure for augmenting the generation and dissemination of knowledge, both interdisciplinary research teams and technical professionals with expertise in algorithm creation, system operations, and applications development are essential. Graduate programs that emphasize these capacities in their students are needed, as are innovative organizational and educational models that implement policies and procedures empowering cyberinfrastructure (NSF Cyberinfrastructure Council, 2006). The evolution of graduate education in the directions outlined earlier would increase the pool of human talent positioned to take full advantage of cyberinfrastructure capabilities for research and for education. However, substantial changes in faculty roles, teaching practices, assessment strategies, and university operations are necessary if this evolution is to occur.

Important research questions that the next five years of advances in cyberinfrastructure could help to answer include:

> What are the three-dimensional structures of all of the proteins encoded by the human genome and how does structure influence their function in a human cell? What patterns of emergent behavior occur in models of very large societies? How do massive stars explode and produce the heaviest elements in the periodic table? What sort of abrupt transitions can occur in Earth's climate and ecosystem structure? How do these occur and under what circumstances? If we could design catalysts atom-by-atom, could we transform industrial synthesis? What strategies might be developed

> to optimize management of complex infrastructure systems? What kind of language processing can occur in large assemblages of neurons? Can we enable integrated planning and response to natural and man-made disasters that prevent or minimize the loss of life and property? (NSF, op. cit., p.11).

By 2010, researchers plan to address problems such as these through peta-scale computing: computers operating at sustained speeds on actual research codes of 10^{15} floating point operations per second (petaflops) and working with extremely large data sets on the order of 10^{15} bytes (petabytes).

These advances in computation are complemented by gains in the organization, access, and usage of data. Novel scientific methods that enable new understandings through intelligent adaptation to evolving conditions are emerging through the dynamic integration of data generated through observation and through simulation. New methods of data mining, visualization, and analysis are enabling a wide range of scientific advances in areas ranging from DNA sequencing and cosmology to the temporal and spatial analysis of socio-economic dynamics and ecosystem analysis.[3] These advances are increasing the productivity of scholarship, speeding the application of research findings to develop better products and services, and enhancing effective teaching and learning across the entire spectrum of academic disciplines and fields.

Universities are key participants in the development of standards for data, metadata, and ontologies, as well as in sharing research, resource, and reference collections. Both these activities are increasingly central to the effective conduct of research and graduate education. International communities of scholars are now active in creating data management and curation strategies.[4] University-based scholars and librarians can make substantial contributions in this area by sharing best practices; harvesting, indexing, and disseminating faculty-developed research and education materials; and supporting infrastructures based on open-source and interoperability standards.

Virtual organizations and shared cyberinfrastructure services are exciting and challenging frontiers for graduate education and research. Many scholars are gaining access to resources unaffordable by individual institutions, such as sophisticated experimental facilities and field equipment, distributed instrumentation, sensor networks and arrays, mobile research platforms, high performance computing systems, remote data-collections, and advanced tools for simulation, analysis, and visualization (NSF, op cit).

Communities of researchers can develop collective insights in real-time and across space. Virtual organizations ("collaboratories," "co-laboratories," "grid communities," "gateways," and "portals")[5] are emerging that are revolutionizing the conduct of research and education.

Virtual Organizations

Scientists are now defining the structure of the North American lithosphere with an extraordinary level of detail through EarthScope, which integrates observational, analytical, telecommunications, and instrumentation technologies to investigate the structure and evolution of the North American continent, and the physical processes controlling earthquakes and volcanic eruptions. The Integrated Primate Biomaterials and Information Resource assembles, characterizes, and distributes high-quality DNA samples of known provenance with accompanying demographic, geographic, and behavioral information to advance understanding of human origins, the biological basis of cognitive processes, evolutionary history and relationships, and social structure, and provides critical scientific information needed to facilitate conservation of biological diversity. The Time-sharing Experiments for the Social Sciences (TESS) allows researchers to run their own studies on random samples of the population that are interviewed via the Internet. By allowing social scientists to collect original data tailored to their own hypotheses, TESS increases the precision with which social science advances can be made (NSF, op. cit., pp. 26-27).

The challenges of developing virtual organizations across graduate schools on both the national and international level are profound, yet the advantages to research and education from such an evolution are compelling.

A potential concern is that the evolution of research cyberinfrastructure may privilege the physical and biological sciences over the social and behavioral sciences, as well as over other fields of knowledge that do not describe themselves as "sciences." While only time will tell if this concern is justified, early examinations of the cyberinfrastructure vision seem positive about its potential value for the full range of graduate research and education.

Cyberinfrastructure and the Social, Behavioral, and Economic Sciences

In 2005 the National Science Foundation convened a workshop on cyberinfrastructure and the social sciences. The findings of that workshop concluded that (Berman & Brady, 2005):

1. *Cyberinfrastructure can make it possible for the SBE [social, behavioral, and economic] sciences to make a giant step-forward* – Cyberinfrastructure can help the social and behavioral sciences by enabling the development of more realistic models of complex social phenomena, the production and analysis of larger datasets (such as surveys, censuses, textual corpora, videotapes, cognitive neuroimaging records, and administrative data) that more completely record human behavior, the integration and coordination of disparate datasets to enable deeper investigation, and the collection of better data through experiments and simulations on the Internet. What is revolutionary is that Cyberinfrastructure provides the ability to do these things at unprecedented scale and intensity using distributed networks and powerful tools just at a time when social and behavioral scientists face the possibility of becoming overwhelmed by the massive amount of data available and the challenges of comprehending and safeguarding it.
2. SBE scientists can help CISE [computer and information sciences & engineering] researchers design a functional and effective Cyberinfrastructure which achieves its full potential – Cyberinfrastructure requires unprecedented organization, coordination, and integration and will have immense impact on the social dynamics, technological resources, and communication and interaction paradigms for both science and society. SBE leaders are needed to help guide the design, development, and deployment of a functional Cyberinfrastructure: Organizational researchers and political scientists can help develop appropriate management, decision-making and governance structures for Web-enabled research communities and the Cyberinfrastructure providers that support them. Economists can design incentive-compatible resource allocation methods for the sharing of multiple and diverse resources. Behavioral scientists can help develop

> better modes of human-computer interaction. Sociologists can analyze the implications for knowledge production of social networks developed on the Web. Psychologists and linguists can help computer scientists develop computer programs that understand, utilize, and translate natural languages... Working together, SBE scientists and computer scientists can develop better statistical and analytical methods for dealing with data, and they can understand and control the malevolent behaviors that threaten to limit the achievement of the potential of Cyberinfrastructure.
>
> 3. Together, SBE and CISE researchers can assess the impacts of Cyberinfrastructure on society and find ways to maximize the benefits of Cyberinfrastructure – Just as the Internet has forever changed the way we live and work, Cyberinfrastructure has the potential to accelerate innovation and discovery within the science and engineering community. However, it is critical to understand the way Cyberinfrastructure will impact the community and to use this information to improve Cyberinfrastructure. It is already an accepted part of the mission of the SBE sciences to assess societal impact, but it is particularly important to assess the impacts of Cyberinfrastructure for engineering and the sciences. Social and behavioral scientists can be especially helpful in understanding changes in social interactions, changes in jobs and income, the impact of policy, and new conceptions of privacy and trust in the networked world. By increasing our understanding of these changes, SBE and CISE researchers can work with NSF communities to maximize the societal benefits from Cyberinfrastructure (p.5).

Other fields and disciplines can likely generate comparable statements about the value of their perspectives in attaining the benefits and minimizing the challenges of cyberinfrastructure.

Implications of this Cyberinfrastructure Vision for Graduate Education

Cyberinfrastructures developed for research purposes also create intriguing opportunities to transform graduate education and call for “new methods to observe and to acquire data, to manipulate it, and to represent it [that] challenge the traditional discipline-based graduate curricula" (NSF, op. cit., p. 32). Scientific and educational resources can now pervade a wide variety of settings, rather than being accessible only in limited, specialized locations. Real-time data collection can enable assessing students' educational gains on a formative basis, providing insights into the microgenetics of learning the complex knowledge and skills characteristic of graduate education. Students can customize and personalize learning environments to a degree never before possible. Extensive "online" learning can complement conventional face-to-face education, and ubiquitous, pervasive computing can infuse smart-sensors and computational access throughout the physical and social environment.

Accomplishing these shifts requires more than the creation and maintenance of the cyberinfrastructure itself; it also requires a commitment to professional development opportunities to use this infrastructure and take full advantage of its potential for fostering new structures of collaborative learning (NSF, op. cit., pp. 32-33). New disciplines also may result from these emerging methods of education, fields as important as the relatively new areas of computer science, mathematical biology, genomics, environmental science, and astrophysics are today.

During 2004-05, with NSF funding, four workshops attended by experts in education were convened by the Computing Research Association (CRA). The foci of these workshops were, respectively (CRA, 2005):

- Modeling, Simulation, and Gaming Technologies Applied to Education
- Cognitive Implications of Virtual or Web-enabled Environments
- How Emerging Technology and Cyberinfrastructure Might Revolutionize the Role of Assessment in Learning
- The Interplay between Communities of Learning or Practice and Cyberinfrastructure

Collectively, these groups envisioned a cyberinfrastructure that "provides: 1) unprecedented access to educational resources, mentors, experts, and online educational activities and virtual environments; 2) timely, accurate assessment of student learning; and 3) a platform for large-scale research on education and the sciences of learning… Moreover, the new educational cyberinfrastructure will make it possible to collect and analyze data continually from millions of educational activities nationwide over a period of years, enabling new advances in the sciences of learning and providing systematic ways of measuring progress at all levels" (CRA, op. cit., p.1).[6]

The CRA report details projected shifts in education that cyberinfrastructure will facilitate as it develops. Some of these resonate with the visions of improving graduate education described earlier. As an illustration of CRA's forecasts about the evolution of learning and teaching:

> As STEM research becomes increasingly collaborative, distributed, and dependent upon access to large amounts of computational power and data, students as well as teachers and educational decision makers at all levels will need to learn how to think with data—using diverse forms of data, information resources, tools, and services in many different fields of study to support making a broad range of decisions. They will need to become proficient in navigating a rich universe of data resources; in engaging with statistics, probability and evidence-based argumentation; and in discerning the authenticity, quality and reputation of these data sources. Emerging tools and frameworks for interactive and dynamic visualizations of patterns in data will be integral to these new literacies for thinking and decision making (CRA, op. cit., pp. 5-6).

However, the report cautions that networked systems can create unexpected side-effects, citing usage of data and usage privacy and accessibility, as well as the potential intertwining of formal schooling and assessment with ubiquitous informal learning.

A "Simulation" Scenario

The NSF Cyberinfrastructure Council (2006) provides a scenario of how advanced visualization and simulation capabilities could advance education:

Imagine an interdisciplinary course in the design and construction of large public works projects, attracting student-faculty teams from different engineering disciplines, urban planning, environmental science, and economics; and from around the globe. To develop their understanding, the students combine relatively small self-contained digital simulations that capture both simple behavior and geometry to model more complex scientific and engineering phenomena. Modules share inputs and outputs and otherwise interoperate. These "building blocks" maintain sensitivity across multiple scales of phenomena. For example, component models of transportation subsystems from one site combine with structural and geotechnical models from other collections to simulate dynamic loading within a complex bridge and tunnel environment. Computational models from faculty research efforts are used to generate numerical data sets for comparison with data from physical observations of real transportation systems obtained from various (international) locations via access to remote instrumentation. Furthermore, learners explore influences on air quality and tap into the expertise of practicing environmental scientists through either real-time or asynchronous communication. This networked learning environment increases the impact and accessibility of all resources by allowing students to search for and discover content, to assemble curricular and learning modules from component pieces in a flexible manner, and to communicate and collaborate with others, leading to a deep change in the relationship between students and knowledge. Indeed, students experience the profound changes in the practice of science and engineering and the nature of inquiry that cyberinfrastructure provokes (p.31).

Comparable vignettes can illustrate educational opportunities in constellations of fields across the sciences and social sciences.

A “Serious Game” Scenario

The Computing Research Association report on educational visions for cyberinfrastructure also presents a vignette of a “serious game”:

Learners cooperate in designing and conducting a mission to Mars, in the context of a game-based simulation. In the course of the project they carry out a variety of STEM-related learning activities, spanning physics, chemistry, biology, engineering and mathematics. These become springboards for seeking other learning resources outside the game, and collaborating with other learners in online working groups. Learners access online science and engineering data sets and models in order to compare their predictions against results from space scientists. They receive guidance in inquiry skills, metacognitive learning skills, and collaboration skills. The game itself is constructed and adapted through the collaborative efforts of the participating learners. In his earth sciences course, John, for

> example, studies terrain data from Mars Rover missions and creates a model of the Martian terrain to be explored by others. Manuela, in her high-school engineering class, designs an autonomous rover vehicle to collect geologic samples and constructs a simulation of her rover design for use in the mission. She can then compare her model's performance in the simulation against records of actual Mars Rover missions. Sherry, the teacher, is assisted by virtual assistant teachers (intelligent tutors) embedded in the game that help her monitor learner progress and offer guidance and challenges. One of Sherry's virtual assistants reports that Manuela is having difficulty getting the controller of her virtual robot to work, and is not availing herself of online resources, so Sherry suggests that she discuss her design with an online community of robot enthusiasts. Data collected from learner performance within and surrounding the game provide the teacher with documentation and evidence of learning progress relating to curriculum standards and goals. In some contexts this may replace the need for standardized tests, but in others the teacher already has sufficient evidence to predict that the learners will meet the required standards (p. 7).

Some of the most innovative examples of the use of cyberinfrastructure in education are to be found in pre-college education: in simulation scenarios and game-based scenarios. One may ask why graduate educators should track the evolution of pre-college schooling. Improvements in K-12 and undergraduate education will influence the knowledge, skills, attitudes, and learning styles of students entering graduate work. If in the future entering graduate students have deeper understandings and more sophisticated skills than current initiates, this shift offers the opportunity to reconceptualize graduate education towards inculcating more advanced knowledge than currently possible.

In fact, pre-college, undergraduate, and graduate education may link more closely together should the digital Lifelong Learning Chronicles (LLCs) envisioned in the Computing Research Association depiction of educational cyberinfrastructure come to pass:

> LLCs can offer rich and compelling information to a wide variety of stakeholders. For example, individual learners would have the data they need to make informed decisions about their own learning—what knowledge they need to study, what learning resources are

> available that best align with their interests and learning style (instead of the one-size-fits-all textbook), what metacognitive skills could be improved, and what strengths and weaknesses they have that may influence future academic and employment choices. Learners will no longer have to take a single-shot, high-stakes assessment, but instead can benefit from continuous embedded assessments that provide both multiple opportunities to demonstrate their strengths… For all these stakeholders, a major benefit of the continuous learner data collection is the possibility of much more rapid, informative, and accurate feedback and responsiveness than is possible with today's practices of occasional high-stakes and summative tests administered by teachers, instructors, and testing agencies during the school year. Data collection can go beyond traditional measures of domain content acquisition to include records of such factors as the processes learners have used in solving problems, information about whether learners are asking for help appropriately, and the way that learners may collaborate, cooperate and argue with each other. Faster cycles of feedback not only would foster better instructional decision making, but research in learning technology that is better focused on effective design and appropriate uses of that technology as well (pp. 19-20).

To the extent that research communities also engage in forms of individual and collective learning, advances in instructional design based on LLCs as a record of microgenetic learning may also empower faster and deeper evolution of insights by scholars, particularly in graduate university settings.

However, realizing all these benefits of educational cyberinfrastructure depends on graduate faculty transforming their instructional practice to take advantage of these new capabilities. For most faculty, such a shift will require extensive professional development, even though they may already have made comparable changes in how they conduct their research. Past experience has shown that graduate universities would need to provide substantial incentives to persuade many faculty to undertake such professional development. Cyberinfrastructure may be perceived as having some advantages over face-to-face professional development opportunities, such as user-centered control over the level and timing of engagement, that faculty seeking professional development in these areas find particularly appealing.[7] But without policies that promote change, psychological and cultural barriers are likely to impede evolution long after all technical and economic challenges are overcome.

This CRA vision of educational cyberinfrastructure is "extreme" in the sense that every application of information and communications technologies to learning is imagined as both effective and technologically/economically feasible. The history of technology forecasting documents that the short-term impacts of advances are generally overestimated, while the long-term, sometimes unexpected consequences are typically underestimated. Certainly, such a generalization may apply to the effects of cyberinfrastructure on research and teaching over the next two decades. What are the "steppingstones" in the present that could speed the evolution of this vision for graduate universities' practices and policies in research and education?

Next-Stage Impacts of Information and Communications Technologies (ICT) on Graduate Research and Education

Some emerging technologies provide only incremental improvements on existing educational modalities, often through changes in delivery system (Dede, in press-a). Weblogs ("blogs") and podcasts fall into this category; blogs are similar to an electronically indexed daily diary, and podcasts are much like a recorded radio show. While such media can provide gains over their prior counterparts, usually the hype surrounding them exceeds their actual capacity for adding educational value. In the case of blogs and podcasts, for example, the real value lies not in the media themselves, but in the opportunities for self-publishing and knowledge sharing they enable. The field of education is hopefully outgrowing the "This new medium is magic!" syndrome.

Other emerging technologies offer new, more substantial capabilities for learning. For example, "wikis" provide the opportunity for multiple participants to co-create documents across distance. A wiki is a collaborative website that allows multiple authors to create, edit, and delete content. We know this capability is very useful in face-to-face collaborative learning, exemplified by such activities as design team members sketching simultaneously on a large, shared whiteboard, annotating each other's ideas. As the curriculum standards championed by the Partnership for 21st Century Skills (2005) illustrate, the capability to provide virtual collaborative workspaces shared across distance is valuable not only for learning, but also for preparing graduate students to work in a global, knowledge-based economy. Graduate schools may find wikis particularly valuable in distance learning situations in which a small number of local students in a specialized field can engage in powerful forms of face-to-face peer collaboration in learning communities of remote counterparts.

Another type of emerging technology likely to add significant value for learning in graduate education is "sociosemantic networking" (Dede, in press-a). The many websites created early in the 21st century fueled efforts to categorize and organize the Web in order to empower users seeking to find "needles in haystacks." Google, Yahoo!, AOL, and others developed complex page ranking systems and algorithms to link information seekers to pertinent resources. Finding what one wanted on the Web became easier, but organizing and saving these resources was increasingly harder. Online communities clamored for intuitive ways to store and share their "gold mine" resources with friends and colleagues—enter the social bookmarking revolution.

2003-2004 marked the release of del.icio.us, furl, simpy, and Flickr, some of the more popular online social bookmarking communities (Seldow, 2006). Instead of saving websites to their browsers and photos to their computers, individuals began saving bookmarks and photos online, sharing them with others, and – most important – labeling the items with words they could remember. This bottom-up, participant-driven method of identifying bookmarks and photos with personalized keywords adopted the industry moniker "social tagging," and the process of creating online, community-based meaning for content was born.

Social tagging affords students the ability to use their words to describe content and their words to search for content. Seldow (op. cit.) proposes that social tagging of files and web pages within student communities is a direct and intuitive way to label and access relative content, parallel to how students think about resource navigation in their lives outside of school and easier than the top-down, elaborate, nested hierarchies of pre-specified, narrowly defined terms that characterize formal classification frameworks, such as the Dewey Decimal System. As the Computing Research Association report notes:

> In the virtual world, social networking functions (such as face books and recommender systems) can enable learners to aggregate into communities of interest and evolve into communities of learning or practice. We need to understand the formation of these communities and ways to facilitate the contribution of cybersocial networking to the learning and engagement of students and teachers. Additionally,

> social capital influences who participates and the focus of community activity, which leads to various learning outcomes for different types of learners and groups (p.29).

New ways of understanding how to structure knowledge in order to facilitate learning may emerge, as scholars develop bridges between historically-derived, top-down terminology and conceptual frameworks from disciplinary fields and bottom-up, colloquial language and cognitive mappings from sociosemantic networking. Such an approach may also aid in recruiting students from diverse backgrounds, since bottom-up articulation of language and knowledge may provide ways to develop scholars who begin with psychological and cultural perspectives for which current disciplinary terminology poses barriers. As a very simple example of this complex learning issue, overly symbolic approaches to teaching can turn away students with considerable intellectual capacity and enthusiasm who think in visual ways not well captured by the historic formalisms of a field.

Immersive Collaborative Simulations

Another type of emerging educational technology that provides a bridge from the present to full-fledged cyberinfrastructure is immersive collaborative simulations. Immersion in virtual environments and augmented realities shapes participants' learning styles, strengths, and preferences in new ways beyond what using sophisticated computers and telecommunications has generated thus far, with multiple implications for graduate education. Dede (2005) describes "learning styles" enhanced by mediated immersion in distributed-learning communities based on multi-user virtual environment (MUVE) and augmented reality (AR) interfaces: (a) fluency in multiple media; (b) learning based on collectively seeking, sieving, and synthesizing experiences, rather than individually locating and absorbing information from some single best source; (c) active learning based on experience (real and simulated) that includes frequent opportunities for reflection; (d) expression through non-linear, associational webs of representations rather than linear "stories" (e.g., authoring a simulation and a webpage to express understanding, rather than a paper); and (e) co-design of learning experiences personalized to individual needs and preferences.

Immersive Collaborative Simulation Interfaces

Three complementary technological interfaces are now shaping how people learn, with multiple implications for education (Clarke, Dede, & Dieterle, in press).

- The familiar *"world- to- the- desktop"* interface provides access to distributed knowledge and expertise across space and time through networked media. Sitting at their laptop or workstation, students can access distant experts and archives, communicate with peers, and participate in mentoring relationships and virtual communities-of-practice. This interface provides the models for learning that now underlie most tools, applications, and media in graduate education.
- Emerging *multi-user virtual environment (MUVE)* interfaces offer students an engaging "Alice in Wonderland" experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other participants and with computerized agents. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures. This type of "mediated immersion" (pervasive experiences within a digitally enhanced context), intermediate in complexity between the real world and paint-by-numbers exercises in K-12 classrooms, allows instructional designers to construct shared simulated experiences otherwise impossible in classroom settings. Researchers are exploring the affordances of such models for learning in K-12 education (Clarke et al., 2006; Barab et al., 2004).
- *Augmented reality (AR)* interfaces enable "ubiquitous computing" models. Students carrying mobile wireless devices through real world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or an historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students' experiences and interactions. Researchers

are starting to study how these models for learning aid college students' engagement and understanding (Klopfer et al., 2004; Klopfer & Squire, 2007).

If we examine students' technology use outside of classrooms, we see these shifts in learning styles happening in their informal, voluntary educational activities (Clarke et al, op cit). For example, while one person sitting in front of a console game is still prevalent, collaborative, mediated gameplay is rising. X-box live and Nintendo DS devices enable participants to interact during gameplay across distance and space. Massively multi-player online games (MMOG), such as the World of Warcraft (Blizzard Entertainment) and Everquest (Sony Online Entertainment), bring players together online where they can interact in a virtual collaborative context. Emerging communities such as "modding," in which users create new content for games (often contributing to a shared database of models), and "machinima," in which users create new content via video capturing techniques, are further shaping how participants now express themselves via collaborative digital experiences. People of all ages are forming networked communities around games and movies, in which they share codes and strategies and build collaborative clans working together to fulfill quests. In their learning processes, many of these distributed communities among participants parallel the activities of 21st century professionals in knowledge-based workplaces.

Despite the proliferation of sophisticated technology use outside of classrooms, typical academic settings seldom leverage any of the three immersive collaborative simulation interfaces described in the box above for teaching and learning. Many faculty require students to turn off their cellphones and laptops in class, rather than using these as a powerful resource for interactive learning through "back-channel meta-communication," which would allow students to provide feedback to teachers. Moreover, when employed, computers and telecommunications are generally used to streamline the delivery of content, ignoring information technology's capabilities to: 1) support learning in real-world contexts, 2) connect learners to experts and communities of peers, 3) provide visualization and analysis tools for thinking with data, 4) scaffold problem solving that enables more complex reasoning than possible otherwise, and 5) enable opportunities for feedback, reflection and revision of knowledge construction (Bransford, Brown, & Cocking, 2000). Below are sketched two examples of how interfaces for immersive mediated experiences can now shape students' learning in pre-college and college education. If these immersive, collaborative media prove powerful for learning, this will influence the types of knowledge, skills, and learning styles/strengths students bring to collegiate and graduate studies.

Multi-User Virtual Environments

MUVEs can offer learning experiences intermediate in complexity between follow-the-recipe laboratory sessions and the intricacy of real world situations inaccessible to K-12 students, such as tracking the spread of a disease in a community. The author heads a project funded by the National Science Foundation to enhance middle school students' educational outcomes in science through design-based research on one such MUVE-based learning experience, River City (http://muve.gse.harvard.edu/rivercityproject/). Students leave their classroom setting to travel through a historically accurate 19th century virtual city (Clarke et al, op cit). They try to figure out why people are getting sick and what actions can remove sources of illness. They talk to various residents in this simulated setting, such as children and adults who have fallen ill, hospital employees, merchants, and university scientists (Figure 1).

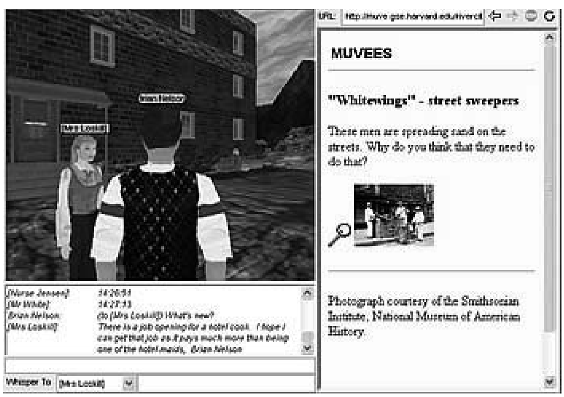

Figure 1: Talking with an Agent

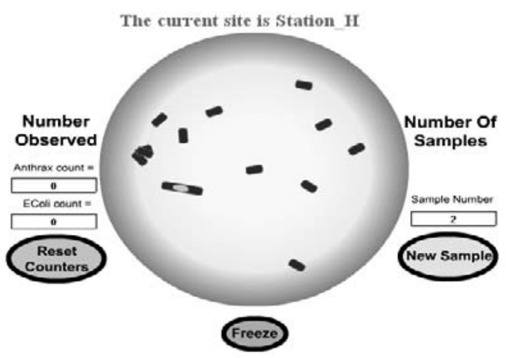

Figure 2: Tool for Collecting Water Data

Participants go to different places in the town and collect data on changes over time, acting in gradually more purposeful ways as they develop and test hypotheses. They help each other and also find experts and archives to guide them. Further, students use virtual scientific instruments, such as microscopes to test water for bacteria (Figure 2). This immersive simulation allows them to conduct an experiment by changing an independent variable they select, then collecting data in the city to test their hypothesis. Students not only hypothesize what would happen if a sanitation system were built—they can actually visit the city with a sanitation system added and see how this change affects the patterns of illness. Early research on students' learning of sophisticated inquiry skills and complex knowledge (for the developmental level of middle school pupils) is very promising.

Augmented Reality

As an illustration of immersive collaborative simulation based instead on the ubiquitous computing interface, Eric Klopfer of MIT and his colleagues are developing augmented reality (AR) handheld-computer simulations that embed high school and college students inside lifelike problem-solving situations to help them understand complex scientific and social dynamics (http://education.mit.edu/ar). Participants in these distributed simulations use location-aware handheld computers (with GPS technology), allowing users to physically move throughout a real-world location while collecting place-dependent simulated field data, interviewing virtual characters, and collaboratively investigating simulated scenarios (Dede, 2005). For example, Klopfer's Environmental Detectives AR simulation engages high school and university students in a real-world environmental consulting scenario not possible to implement in a classroom setting. Students role-play environmental scientists investigating a rash of health concerns on the MIT campus linked to the release of toxins in the water supply (Klopfer et al, 2004). Working in teams (Figure 3), players attempt to identify the contaminant, chart its path through the environment, and devise possible plans for remediation.

Figure 3: Students in Augmented Reality

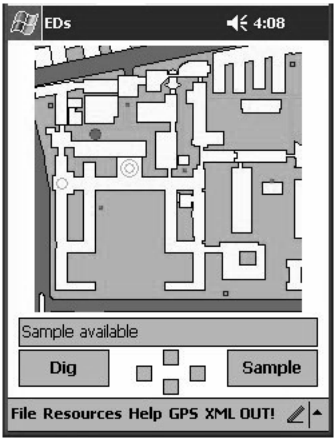

Figure 4: Handheld Location on Campus

As participants physically move about campus, their handheld devices respond to their location (Figure 4), allowing them to collect simulated field data from the water and soil, interview virtual characters, and perform desktop research using miniwebs of data. At the end of the exercise, teams compile their data using peer-to-peer communication and synthesize their findings. Initial research on Environmental Detectives and other AR-based educational simulations demonstrates that this type of immersive, situated learning can effectively engage students in critical thinking about authentic scenarios (Klopfer & Squire, in press). Students participating in these simulations indicated that they felt invested in the situations and were motivated to solve the problem. They moved nearly seamlessly between the real world and the information being presented to them on their handheld computers as they collected data from virtual scientific instruments and accounts from virtual experts and witnesses. Students were most effective in learning and problem-solving when they collectively sought, sieved, and synthesized experiences rather than individually locating and absorbing information from some single best source.

Examples of Early-Stage, Graduate-level Educational Cyberinfrastructure

As a concrete example of an early-stage use of MUVEs in graduate education, AppEdTech is a virtual world running on an ActiveWorlds (http://www.activeworlds.com) Galaxy Server at Appalachian State University (Riedl, Bronack, and Tasner, 2005). The browser presents the user with four distinct areas (see Figure 5):

1. A central 3-D view of the world, either in first person view or a third person view from behind the user's avatar.
2. A text-based chat space below the 3-D view that allows users to interact with other users.
3. A web space to the right of the 3-D view that presents the user with web pages that connect interactions of the user with objects in the world.
4. A utilities space to the left of the 3-D view and chat space provides the user with access to help files, telegrams sent by other users, teleports (similar to bookmarks on a web browser that allow the user to go directly to a place in the 3-D environment), contacts (a listing of people the user wishes to interact with that provides information on the contact, such as whether the contact is online, and contact resources such as the ability to send telegrams or join others where they are in the 3-D world).

*<u>Figure 5</u>: The AppEdTech Interface (3rd Person View)
Upon Entrance to the World*

To date, seven courses to date are taught in AppEdTech (Riedl et. al, op. cit.). Each is unique in appearance and operation according to the nature of the content and the form of interaction that is desired in order to meet class goals. As one illustration of how this interface is used in teaching, a course that explores telecommunications in education is organized around four distinct areas that are represented by four modern buildings located around a plaza (see Figure 6):

1. One focuses on a book the class is reading and provides a format for interactions connected to the book.
2. Another focuses on the opportunity to walk through a network, either from the Internet to the computer or vice versa, providing the student information about the components of the network.
3. This area focuses on various telecommunications tools that can be and are used in educational settings and connections to the class discussion board to share thoughts, ideas, and questions about these tools.
4. This area explores the uses of telecommunications tools to enhance a classroom or as distance education media.

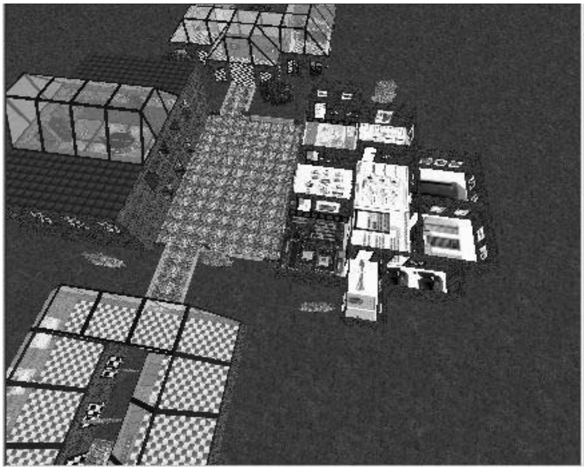

Figure 6: *An overview of the class area for the telecommunications class, consisting of four buildings grouped around a central plaza. The building on the right has no roof. It is a virtual tour of a network as students are encouraged to "fly" to see parts of the network from above.*

Participating faculty report that they have begun thinking about classes differently (Riedl, et al., op. cit.).

> In the past we have found ourselves thinking of classes as a series of sessions that are held on certain days. Even our web-supported classes have tended to follow this pattern. But by putting the classes in a three-dimensional world we have found ourselves thinking differently about how students might move through them. We still find ourselves providing resources and activities but leaving more opportunities for the students to take their own paths through those resources and activities… We still may present the class as a linear series of experiences, such as in the web design and planning classes, but we find ourselves more open to providing more choices for the students and we often use the 3-D world to present those choices by providing different paths through the class site (as in the class on integrating computer technology into instruction and the class on hypermedia) or by presenting a plaza that allows the students to move in any direction. (p.11).

Faculty also report that students "are afforded many and frequent opportunities to interact with others who are in the same course, even if they are not in the same section of the course, and with instructors from other sections of the course, or even from different courses or with students who are at different stages of their program of study, creating a more natural and richer community in which to participate."

Another illustration of early-stage work towards on the cyberinfrastructure vision on educational visualization described earlier is the Envision Center for Data Perceptualization (www.envision.purdue.edu) at Purdue University (Grush, 2006). Visualization is a powerful method for both teaching and research (IEEE Computing Society, 2006). The Purdue Envision facility was conceived by a group of faculty who saw a need for a campus building that would support visualization and data perceptualization in research and teaching. Traditional text and 2D displays were falling short as a means to represent data and concepts, and technology offered new ways to involve a variety of senses—visual, auditory, touch, and more—to immerse users in environments for exploration, interaction, and discovery. The Center provides its users opportunities to work with varied interactive media for interpreting data and concepts, so students and faculty can incorporate the most effective models in their research and education.

Among the high-end technologies supported are "virtual theater," "motion capture," "tiled wall display," and "access grid" (Grush, op. cit.):

> **VR Theater:** VR Theaters immerse users in the environment they are viewing (see Figure 7). The users are not just passive observers in the computer-generated world, but are interacting with the various components of the environment in real time. Envision's VR Theater is a Fakespace FLEX system featuring three 10' x 8' panels for rear projection of large-scale 3D images. These movable screens can be easily and rapidly rearranged to form a semi-enclosed room with three walls plus a fourth panel as the floor. This arrangement creates a 3D immersive virtual environment. The VR Theater is also equipped with a state-of-the-art tracking system that allows corrective perspective rendering and direct interaction with the virtual environment. A 5-channel speaker system in the corners of this facility further contributes to the effect by adding surround sound cues to the virtual reality environment.

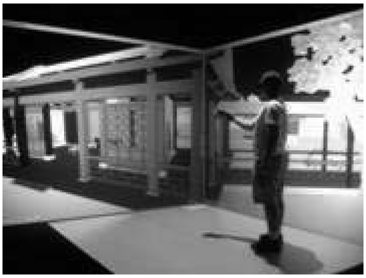

Figure 7: VR Theater

Figure 8: Motion Capture

Motion Capture: The Envision Center houses an STT Motion Captor (http://www.metamotion.com/captor/motion-captor-workflow.htm) optical motion capture system that is operated in collaboration with the Department of Visual and Performing Arts (Figure 8). This system is composed of six infrared cameras on tripods and as many as three linked computers.

Tiled Wall: The tiled display wall at the Envision Center is a 12' x 7' high-resolution display made up of a grid of 12 smaller projection displays controlled by several computers working together (Figure 9). The wall is capable of displaying 4,096 pixels horizontally and 2,304 pixels vertically for a total of 9.4 million pixels—about 5 times the resolution found on a typical desktop workstation. The display system is extremely versatile and can be used for 2D, 3D, or stereo production of single, large-scale continuous images. A 13-node PC cluster with Nvidia (www.nvidia.com) GeForce FX 3000G graphics cards provide the computation and rendering for the tiles.

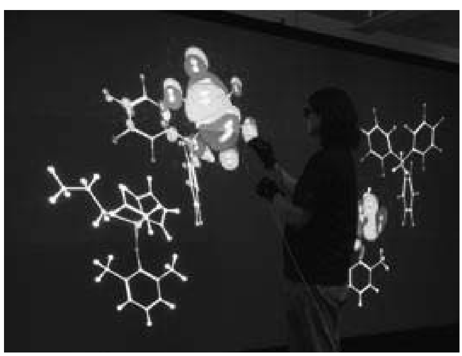

Figure 9: Tiled Wall

Figure 10: Access Grid

Access Grid: The Envision Center places a premium on collaborating with researchers and student groups spread over the entire world. Users of the center at Purdue can work through the Access Grid (www.accessgrid.org) on projects that incorporate both local and remote presentation and interactive environments and visualizations that may require multimedia large-format displays, high-end presentation devices, interfaces to middleware, and other networked resources (Figure 10).

Computer graphics faculty, research faculty who employ visualization in their science, and teaching faculty in all undergraduate and graduate departments throughout the university use the center. Since its opening in 2004, the center has supported more than 30 research projects, offered 4 different courses for credit to students, and has been involved in several research proposals. The single largest impact to date has been the broadening of visualization in support of research at Purdue.

As another illustration of emerging cyberinfrastructure for research and teaching, the Genome Consortium for Active Teaching (GCAT) engages undergraduate students in genomics experimental design and data analysis (Campbell et al., 2006). Participating instructors use DNA microarrays provided by GCAT in student-led interdisciplinary research projects (http://www.bio.davidson.edu/projects/gcat/gcat.html). Faculty have the opportunity to master leading edge technology, while students learn about the importance of quantitative data analysis. To date, about 5000 undergraduates from 120 schools have used about 3400 GCAT microarrays. During the 2005-06 academic year, GCAT provided more than 750 microarrays of nine plant, animal and microbial specials, as well as field-tested protocols and teaching aids for faculty.

As a final example of steppingstones towards educational and research cyberinfrastructure, the GEOsciences Network (GEON) project was established in 2002 under the Information Technology Research program of the National Science Foundation (http://www.geongrid.org/). The goal of GEON is to advance the field of geoinformatics to prepare and train current and future generations of geoscience researchers, educators, and practitioners in the use of cyberinfrastructure to further their research, education, and professional goals (Geosciences Network, 2005). GEON is developing cyberinfrastructure and cybertools for data integration, analysis, and visualization in support of integrative science across the range of Earth Science disciplines. Contributions by students at GEON sites across the country are invaluable to the progress and advancement of the project (http://www.geongrid.org/education/students.html). GEON principal investigators are actively engaged in the development of geoinformatics courses in their departments and have begun to collaborate with Computer Science colleagues and students to offer joint courses and projects.

But is this cyberinfrastructure vision the best path for graduate research and education to follow? What are the possible threats such an evolution poses? Is this yet another example of "technological determinism" driving a shift that may not be worthwhile?

Potential Concerns and Risks Associated with Information and Communications Technologies (ICT) in Graduate Research and Education

The Computing Research Association report (2005) articulates some issues about challenges posed by cyberinfrastructure. One set of concerns deals with ethical issues related to privacy:

> One clear example of demands on Cyberinfrastructure, raised particularly with regard to the handling of human data (as opposed to, say, astronomical data), is privacy. Under most conditions of use, data on human subjects and student classroom performance must be anonymized for scientific or public use. There are significant challenges for anonymization, and a community of data privacy and privacy technology researchers has emerged. Further challenges follow from the fact that different stakeholders may have different access needs for data about student or classroom performance. For

> instance, we may wish to provide students and their parents with full access to their own data; teachers with full access to data on students currently in their classes, but only summary access to their current students' past performance; and school community members, administrations and researchers with only certain kinds of summary information (p.32).

These cautions about privacy are echoed repeatedly in the NSF Cyberinfrastructure Council report (2006).

Certainly, the current national security climate has raised many concerns about individual freedoms versus the public good, and complex ethical choices are involved in creating the sophisticated data collection and student assessment systems envisioned for cyberinfrastructure. While resolving the technical issues involved is complicated, those challenges are surmountable via the advance of computing and networking. The harder questions center around wise use of cyberinfrastructure in ways that promote rather than repress the free exchange of ideas.

But many faculty, scholars, and university administrators may have a prior set of concerns about this vision of technology in graduate education. Will cyberinfrastructure actually improve teaching and learning, or will sophisticated learning technologies instead undercut the considerable value of face-to-face instruction and educational community?

Concerns about the Quality of Learning via Media

Over the last century, the evolution of research on distance education provides a context for understanding "mediated" learning (Dede, Brown-L'Bahy, Ketelhut, & Whitehouse, 2004). In the early years of scholarship on this topic, typical studies compared student outcomes in traditional face-to-face classrooms with outcomes in correspondence courses. This type of comparative research, applied again at the appearance of each new medium (e.g., radio, television, computers, the Web), has fostered continuing debate among educational researchers, educators, and policymakers about the differences between teaching at a distance and teaching in the classroom. Overwhelmingly, comparative research methodologies used to contrast face-to-face learning classrooms and mediated learning across distance reveal a "no significant differences" phenomenon (Russell, 1999). Russell catalogued 335 comparative studies of this type, and his resulting bibliography was one of the first comprehensive looks at "no significant differences" findings.

Multiple, modern studies document this research outcome across a wide variety of students, media, and fields.

However, during the 1990's many researchers found troubling flaws in the comparative methodologies used to gauge the effectiveness of online learning. Joy and Garcia (2000) argued "learning effectiveness is a function of effective pedagogical strategies" (p. 33) and should not be measured by delivery systems. Dede, et al. (2002) wrote, "Three decades of research in distance education are largely off-target because studies have typically compared a single medium (such as face-to-face) to another medium (e.g., videoconferencing) for a group… Some students are empowered by each medium, others disenfranchised; the net result is mixed." Comparative studies seemed to tell only a part of the story about the power of interactive media in teaching.

Emerging technologies enable novel applications of theoretical frameworks for teaching and learning that range from constructivist principles of student-centered learning to learning styles based on cultural and affective constructs, as well as learning theories based on distributed cognition and situated learning.[8] "Blended" or "hybrid" courses combine the use of face-to-face teaching with synchronous and asynchronous mediated interaction. "Distributed learning" is a term used to describe such educational experiences, which are distributed across a variety of geographic settings, time, and various interactive media (Dede, et al., 2002). Should the visions of educational cyberinfrastructure presented earlier become a reality, "distance education" may be an obsolete concept, as may the term "face-to-face education." Instead, all instruction may be "distributed," balanced between classroom-based and mediated learning interactions determined by the subject matter, student population, and educational objectives. Emerging interactive media are facilitating such an evolution.

Reconceptualizing Media as Empowering rather than Undercutting Learning

Information and communication technologies (ICT) aid with representing content, engaging learners, modeling skills, and assessing students' progress in a manner parallel to how a carpenter would use a saw, hammer, screwdriver, and wrench to help construct an artifact (Dede, in press-b). The two key points in this analogy are (1) the tools make the job easier and (2) the result is of higher quality than possible without the tools. No instructional ICT is a technology like fire, where one only has to stand near it to get a benefit from it.

Knowledge does not intrinsically radiate from computers, infusing students with learning as fires infuse their onlookers with heat. However, media are able to aid various aspects of learning, such as visual representation, student engagement, and the collection of assessment data.

Determining whether and how each instructional technology can best enhance some aspect of a particular pedagogy is as sensible instrumentally as developing tools that aid a carpenter's ability to construct artifacts. Given that people disagree both about what constitutes good pedagogy and about what are appropriate goals for education, that some scholars argue for certain types of instructional media and against others is not surprising. The core issue is whether there is just one preeminent way of learning/teaching for every student, for every subject, for all legitimate purposes of schooling – a position that people tacitly espouse when they argue that face-to-face learning is the "gold standard" for everyone.

In fact, learning is a human activity quite diverse in its manifestations from person to person (Dede, in press-b). Consider three activities in which all humans engage: sleeping, eating, and bonding. One can arrange these on a continuum from simple to complex, with sleeping towards the simple end of the continuum, eating in the middle, and bonding on the complex side of this scale. People sleep in roughly similar ways; if one is designing hotel rooms as settings for sleep, while styles of décor and artifacts vary somewhat, everyone needs more or less the same conditions to foster slumber. Eating is more diverse in nature. Individuals like to eat different foods and often seek out a range of quite disparate cuisines. People also vary considerably in the conditions under which they prefer to dine, as the broad spectrum of restaurant types attests. Bonding as a human activity is more complex still. People bond to pets, to sports teams, to individuals of the same gender and of the other gender. They bond sexually or platonically, to others similar or opposite in nature, for short or long periods of time, to a single partner or to large groups. Fostering bonding and understanding its nature are incredibly complicated activities.

Educational research strongly suggests that individual learning is as diverse and as complex as bonding, or certainly as eating. Yet theories of learning and philosophies about how to use ICT for instruction tend to treat learning like sleeping, as a simple activity relatively invariant across people, subject areas, and educational objectives. Current, widely used instructional technology applications have less variety in approach than a low-end fast-food restaurant. Moreover, many educational designers and scholars seek the single best medium for learning, as if such a universal tool could exist.

Some believe that one way of learning is universally optimal and therefore develop instructional ICT that embody that approach; others favor a slightly broader Swiss-Army-Knife design strategy that incorporates a few types of instruction into a single medium touted as a “silver bullet” for education’s woes. As Cuban (2001) documents, in successive generations pundits have espoused as “magical” media the radio, the television, the computer, the Internet, and now laptops, gaming, blogging, and podcasting (to name just a few).

Of course, other gurus violently oppose each new type of instructional ICT, seeing that pedagogical approach as undercutting both the true objectives of education and the ways students can best learn. That those pundits learn best face-to-face is compelling evidence in their minds that all other people are similar in their needs and preferences. For example, at present parents and politicians alike are decrying cellphones in schools and banning social networking technologies such as MySpace, despite widespread usage of equivalent tools in 21st century workplaces. Given all these claims and countercharges, small wonder that universities are confused about what types of ICT infrastructures – if any – are effective in education and about how much to invest in instructional technologies.

In light of this confusion, scholars such as Cuban argue that instructional ICT are far less useful than advocates claim and that other forms of educational investment may well produce better results in increasing student learning (Dede, in press-b). Cuban documents that educational technologies divergent from instructors’ current pedagogies are often unused, or utilized ineffectively. He also shows that advocates of ICT in education frequently make extravagant claims that prove hollow; and he expresses doubt that instructional technologies will ever have a transformative effect on learning, teaching, and schooling.

However, a weakness in this position is the tacit assumption, pervasive in most discussions about educational ICT, that instructional media are “one size fits all.” Since no single interactive medium is “best” (including face-to-face instruction), the educational value of narrow types of tools (e.g., Powerpoint, course management systems) is repeatedly debunked, to the chagrin of those who touted them. This instructional improvement strategy is the equivalent of asking a carpenter to build artifacts with only a screwdriver, or only a hammer – then concluding such tools are not useful because each in isolation has limited utility, as well as many weaknesses when broadly applied. In contrast, from an instrumental perspective the history of tool-making shows that the best strategy is to have simultaneously available a variety of specialized tools, rather than a single device that attempts to accomplish everything. This diversity of tools is exactly the design strategy promoted by cyberinfrastructure.

Thus, the nature of the content and skills to be learned shape the type of instruction to use, just as the individual characteristics of the student influences what teaching methods will work well. No educational ICT is universally good; and the best way to invest in instructional technologies is an instrumental approach that analyses the natures of the curriculum, students, and instructors to select the appropriate tools, applications, media, and environments. Assuming that no single form of learning – including face-to-face interaction – is a "gold standard" that works well for all types of students also may aid with another set of concerns that many have about the cyberinfrastructure vision: How would such an evolution affect equity and diversity in graduate education?

Impacts of Cyberinfrastructure on Equity and Diversity in Graduate Education

Graduate schools struggle at present with issues of equity and diversity, in large part because of shortfalls on these dimensions earlier in the educational pipeline, in pre-college and college settings. The Computing Research Association report (2005) recognizes that cyberinfrastructure should address this situation:

> Equity issues must remain a central concern in the [Cyberstructure for Education and Learning for the Future] CELF R&D agenda. Today, students do not have equal access to high-quality instructional resources, nor do they have equal access to highly qualified teachers, particularly for higher-level science and mathematics courses. With the increasing diversity of native languages in the nation's schools and workplaces, the challenges of meeting multilingual needs are an important aspect of this access problem. Ensuring that materials are designed to address the learning challenges of underserved populations and communities is a national imperative (p.33).

In one of its five goals for learning and workforce development, the NSF Cyberinfrastructure Commission report also highlights this challenge:

> Promote broad participation of underserved groups, communities

> and institutions, both as creators and users of CI. Cyberinfrastructure has the potential to enable a larger and more diverse set of individuals and institutions to participate in science and engineering education, research and innovation. To realize this potential, NSF will strategically design and implement programs that recognize the needs of those who might not have the means to utilize CI in science and engineering research and education. To do so, NSF will identify and address barriers to utilization of cyberinfrastructure tools and resources; promote the training of faculty particularly those in minority-serving institutions, predominantly undergraduate institutions and community colleges; and encourage programs to integrate innovative methods of teaching and learning using cybertools (particularly in inner-city, rural and remote classrooms), including taking advantage of international cyber-services to prepare a globally engaged workforce (p.34).

Neither report, however, sketches ways by which cyberinfrastructure provides opportunities that aid graduate schools with issues of diversity and equity. As discussed earlier in this report, emerging interactive media such as sociosemantic networking and immersive collaborative simulations hold promise, since these move our present instructional designs to a broader spectrum of approaches more like eating or bonding than sleeping. However, actualizing this potential of cyberinfrastructure will require time, resources, and political will. Without such a commitment, advances in ICT will likely fall short of the full capabilities they hold for improving graduate education and research.

Conclusion

This commissioned paper provides a forecast, not a prediction, of the probable impact of information and communications technologies on the evolution of graduate research and education. A prediction sees the future as like a roller coaster, a predestined outcome for which we must prepare (Dede, 1990). In contrast, a forecast envisions the future as a tree: one trunk (the past and present), with many branches (alternative futures). Individuals and institutions are like ants crawling up the trunk toward the branches, moving through the present to the future. Decisions made in the present strengthen and weaken various branches (fortify and undermine possibilities) because the choices not made are constrained as alternatives. By the time our present becomes our future, only one branch is left (the new trunk). This forecast is meant to suggest the range of branches we face and the choices involved in shaping the future through actions in the present.

The fundamental goal of futures research and strategic planning is to aid individuals and organizations in managing complexity and uncertainty in their external environments over time. Futures research (this paper) is oriented to articulating the long-range external forces that affect individuals, organizations, and societies; strategic planning (what you do after reading this paper) deals with internal institutional goal setting, resource allocation, and monitoring of progress across multi-year time horizons. Ultimately, the single future that occurs is invented through the interaction of structural certainties (e.g., demographic forces), social-contractual assurances (such as cultural patterns), wild cards, human choices, and indeterminacies. Hopefully, whatever your position about ICT in graduate research and education, this paper has stimulated you to make proactive, strategic decisions in your present to shape our future.

This paper documents that virtual communication and experience can enhance research and learning in powerful ways. However, this augmentation is clearly a supplement, not a replacement, for students' and scholars' immediate involvement in real settings. Thoughtful and caring participation by faculty is vital for making cyberinfrastructural capabilities truly valuable in complementing face-to-face interactions with students and colleagues. How a medium shapes its users, as well as its message, is a central issue in understanding the transformation of conventional classroom education into distributed learning. The telephone creates conversationalists; the book develops "imaginers," who can conjure a rich mental image from sparse symbols on a printed page. Much of television programming induces passive observers; other shows, such as Sesame Street and public affairs programs, can spark users' enthusiasm and enrich their perspectives. We are all struggling to understand what types of people sociosemantic networks and virtual organizations may foster.

As we move beyond naïve presentational/assimilative instructional methods to implement a powerful suite of ways to learn and work across distance and time, society will face powerful new interactive media capable not only of great good, but also misuse. For example, MUVEs can support sophisticated ways of learning that empower action in the real world, or instead can seduce participants into fantasy lives while reality rots around them. Augmented realities can enrich the natural and artifactual worlds through infusing animistic, virtual experiences, or instead can surveil every aspect of our behavior and report "deviations" to those in authority. The most significant influence on the evolution of mediated learning and research in graduate schools will not be the technical development of more powerful devices, but the professional development of wise designers, faculty, and students.

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References

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2 For more information on the Responsive-PhD initiative, see www.woodrow.org/responsivephd; on the CGS initiatives, see www.preparing-faculty.org (PFF) and www.cgsnet.org (RCR).

3 For example, analyses of DNA sequence data are providing remarkable insights into the origins of man, are revolutionizing our understanding of the major kingdoms of life, and are revealing stunning and previously unknown complexity in microbial communities. Sky surveys are changing our understanding of the earliest conditions of the universe and providing comprehensive views of phenomena ranging from black holes to supernovae. Researchers are monitoring socio-economic dynamics over space and time to advance our understanding of individual and group behavior and their relationship to social, economic and political structures. Using combinatorial methods, scientists and engineers are generating libraries of new materials and compounds for health and engineering, and environmental scientists and engineers are acquiring and analyzing streaming data from massive sensor networks to understand the dynamics of complex ecosystems (NSF, op. cit., p.17).

4 For example, the international Consultative Committee for Space Data Standards (CCSDS) defined an archive reference model and service categories for the intermediate and long-term storage of digital data relevant to space missions. This effort produced the Open Archival Information System (OAIS), now adopted as the “de facto” standard for building digital archives, and evidence that a community-focused activity can have much broader impact than originally intended. In another example, the Inter-University Consortium for Political and Social Research (ICPSR) - a membership-based organization with over 500 member colleges and universities around the world - maintains and provides access to a vast archive of social science data. ICPSR serves as a content management organization, preserving relevant social science data and migrating them to new storage media as technology changes, and also provides user support services. ICPSR recently announced plans to establish an international standard for social science documentation. Similar activities in other communities are also underway (NSF, op. cit., p.19).

5 For a glossary of such terms, see: http://edina.ac.uk/projects/crosswalk/Glossary_v1.doc.

6 Members of the expert workshops posited that the influence of cyberinfrastructure on education extend well beyond mere second-order effects of its impact on research. They noted that earlier work foundational to cyberinfrastructure had shaped the evolution of learning and teaching. As one example, the NSF-funded National Science Digital Library (NSDL), which was created to enable widespread access to resources and tools that support innovations in teaching and learning, now contains over 800,000 items from 500 partner libraries and is an important aid in educational improvement at all levels (CRA, op cit).

7 The Computing Research Report notes the potential of cyberinfrastructure for meeting this professional development challenge:

> Online communities of learning have the potential to strongly support professional development. Early research suggests that participation in these communities supports a changed sense of identity and possibility because of their availability, comprehensiveness, and user-centered control over participation; their relative anonymity; the ease of movement within and between communities and roles; and the strength of engagement that comes from interest and access to strong community members. The ability to easily try out roles, from lurking participant to author or program facilitator, provides motivation and opportunity for teachers to reflect on their professional activity, receive feedback and affirmation, and pursue advancement (p.26).

8 As one illustration, the work of Lave and Wenger (1991) in situated learning provides a framework through which to understand how computer-mediated knowledge construction shapes learner experience from social, cognitive and affective perspectives. Roth's research (2001) in situating cognition grows from an epistemological framework that allows a multidimensional analysis of patterns of student work. Lemke's analysis of multiple timescale studies of human activity (2001) utilizes a synthesis of theory and method to allow sophisticated analyses across time and dimensions of behavior; this may reveal more robust findings about how people use interactive media to work and learn. Bielaczyc (2001) has studied developing computer supported collaborative learning communities via focusing on the social infrastructure of these communities and how the design of the tools used to support distance

and classroom learning shapes learner experiences and community building. Each research method listed seeks to gain more understanding of the strengths and limits of mediated learning.

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