

Some Observations Concerning
A Possible National Science Board Study of
Graduate Education in Science and Engineering

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The National Science Board may have an important opportunity to help shape the role of the federal government in graduate education in science and engineering. In response to expressions of concern from national political, corporate, and education leaders about the stresses on the nation's universities, last year the White House formed a multi-agency task force under the auspices of the National Science and Technology Council. The function of this task force was i) to examine data to determine what might be the major stresses in the areas of research, education, and administrative regulations; and ii) to determine what the federal government's role should be in addressing any issues raised by this examination.

Within this context, the National Science Board has been invited to provide its own assessment of the challenges faced by graduate education in science and engineering and its recommendations for the federal role in this important activity. NSB chair, Dick Zare, has formed a task force comprised of Eamon Kelly, Dick Tapia, Diana Natalicio, and Eve Menger to determine an effective NSB role in graduate education. The issues they are considering include:

- i) the link between research and education
- ii) the training of scientists and engineers
- iii) the rationale for federal support of graduate education
- iv) how we pay for graduate education

The NSB will consider this matter in some detail at its October 1997 meeting in Houston.

My remarks are intended to help provide a framework for these discussions.

Past Studies

It is not surprising that during these times of challenge and change in higher education, many of the constituencies involved in the conduct and support of graduate education have expressed concerns. The faculty and their universities generally want to focus on the adequacy and nature of the financial support for graduate education. Graduate students are more concerned with the job market for graduates and the time to degree. The federal government has expressed concerns about the number of advanced degrees relative to market needs and the high percentage of foreign graduate students.

In recent years definitive studies of graduate education in science and engineering have been conducted. These include studies by the NAS/NAE Council on Science, Engineering, and Public Policy; the Government-University-Industry Research Roundtable; the White House Office of Science and Technology; the American Association of Universities; and the National Science Board. In addition, several members of the National Science Board have authored papers expressing their own concerns and recommendations for graduate education.

There have been a number of actions taken to address these issues, such as the NSF Graduate Traineeship Program, the Mellon Foundation project to reduce time-to-degree, and numerous experiments conducted by universities.

Several of the themes running through these studies and programs include:

1. There is general agreement that graduate education in America represents the world's leading effort for producing the next generation of researchers.
2. The complex and rapidly expanding roles in our society played by those with advanced science and engineering training suggest that graduate education needs to be broadened to serve roles beyond simply research and teaching.
3. Included in this broader educational experience should be internship experiences in industry, government, or other types of educational institutions.
4. There is a need for new integrative, practice-oriented graduate degrees, at either the masters or doctorate level, to serve as alternatives to the Ph.D. research degree.
5. There is a need for a better balance among research assistantships, teaching assistantships, fellowships, and traineeships in the support of graduate education.
6. There should be stronger incentives to attract the very best U. S. citizen undergraduates into further graduate study in science and engineering.
7. There needs to be a recognition that the support of graduate education should be the responsibility of all federal agencies that utilize research and employ individuals with advanced degrees.

The GUIRR Study of Stresses on Research and Education at Colleges and Universities

There is an increasing awareness that the academic community is experiencing stress as a result of changes in local, national, and international environments. The pressures of change, coupled with a scarcity of resources, have contributed to a decline in morale on campus among researchers. To understand these concerns, the Government-Industry-University Research Roundtable has injected a grassroots perspective into ongoing, national discussions of the status and future of the academic enterprise. GUIRR has examined faculty and administrator views on how institutions and research sponsoring agencies should respond both to the most troubling issues before them and to the challenges and demands generated by national needs and priorities.

Participants in these discussions made it clear that they understood, to a great degree, that this is a time of change for all institutions in society and that higher

education is not immune from that change. They also stated their belief that during such a period of change, it is essential to protect the fundamental objective of the research university enterprise, namely, creating new knowledge in a free and open environment and fostering the continued development of human capital and scientific personnel.

Many participants stated their strong belief that graduate education is essential to the research enterprise. It is through the process of graduate students working closely with faculty in collaborative research partnerships that we educate and train the next generation of teachers in how to create new knowledge. Some even suggested that the most important role of the federal government in graduate education is its support through research assistantships, since this provides the most direct link between education and research.

There were also those who suggested that it is time to rethink the way we are preparing a generation of students whose career paths may look very different than did the career paths of their mentors. Related but not identical was the theme of concern for the employment dilemma facing graduate students and the need to revise graduate education in accordance with the current and future job market.

The Needs of the Broader Higher Education Enterprise

There were others who expressed deeper concerns about the relationship between the current paradigm of graduate education in America's research universities and the broader needs of higher education. For example, Fred Humphries, president of Florida A&M University, noted that the relationship was becoming more and more tenuous between the research universities, where most of research and graduate education occurs, and the broader higher education enterprise, which consists of almost 3,600 four-year colleges and universities with little research activity. There is a lack of recognition of the role that the research university plays in this broader enterprise. As a result, the discussion related to research and the productivity activity of research does not realistically consider the production function of the graduate research institution and the role that it plays in the health and stress of the other members of the high education continuum.

This same concern about the disparity between graduate education and the needs of the higher education enterprise has been expressed by others. Last year, Robert Atwell, past president of the American Council of Education, used his final letter to the ACE membership to suggest that doctoral education, rather than the crown jewel of American higher education, may be at the root of many of our problems. He suggested that the mismatch between doctoral education and the needs of the higher education marketplace is great. Too many faculty in our research universities are out of touch with the mainstream of higher education—not to mention societal changes and fiscal realities. They go on trying to clone themselves in the persons of their graduate students to assist in their research. As a result, many new Ph.D.s who find jobs in non-research

colleges become frustrated and often exert pressure on these institutions to become research universities—which implies, of course, offering Ph.D.s. Atwell contends that the research/graduate university paradigm has created a pecking order in American higher education that is out of touch with the needs of the nation and the academic marketplace.

There have been concerns expressed about the increasing specialization of graduate education and research and the needs of undergraduate education. Harold Shapiro, president of Princeton University, has noted the increasing disparity between what faculty like to teach and what students need to learn: “There is a growing sense that the competitive demands of specialized scholarship and other developments have placed an irreparable rift between graduate and undergraduate education and may have impaired the capacity of research universities both to remain centers of modern scholarship and to fulfill their broader educational functions. The real problem is that teaching and research may be too closely related. At the root of our unmet challenge in undergraduate education is the failure to distinguish between the transmission of knowledge and the development of a capacity for inquiry, discovery, and continued learning. The predicament is that the faculty is transmitting what they know—and love—with little awareness of what the student needs to learn.”

For several decades the public expectation has been that universities were to create as well as transmit knowledge. This conviction supported strong investment in the scientific, technological, and scholarly preeminence of this nation. This public consensus has begun to erode, and in recent years there has been a decided shift in public attitudes toward the purpose of a university. Support has moved away from research and toward undergraduate education. The concept of faculty as teacher-scholars has narrowed to the belief that most university faculty should be confined primarily to the role of teachers.

The Changing Nature of the Higher Education Enterprise

The higher education enterprise in America consists of over 10,000 institutions of post-secondary education, ranging from small colleges to gigantic state university systems, from religious to secular institutions, from single-sex to coeducational colleges, from vocational schools to liberal arts colleges, from land-grant to urban to national research universities. Despite their diversity, these institutions have long enjoyed a monopoly over advanced education because of geographical location and their certification function through the awarding of degrees. Today all of these market constraints are being challenged as information technology eliminates the barriers of space and time and as new competitive forces enter the marketplace to challenge certification.

In the current paradigm, our colleges and universities are faculty-centered. The faculty has long been accustomed to dictating what it wishes to teach, how it will

teach it, and where and when the learning will occur. Students must travel to the campus to learn. They must work their way through the bureaucracy of university admissions, counseling, scheduling, and residential living. And they must pay for the privilege. If they complete the gauntlet of requirements, they are finally awarded a certificate to recognize their learning—a college degree. This process is sustained by accrediting associations, professional societies, and state and federal governments.

Yet this carefully regulated and controlled enterprise could be blown apart in the near future by several factors.

Financial Imperatives

Since the late 1970s, higher education in America has been caught in a financial vise. On the one hand, the magnitude of the services demanded of our colleges and universities continues to increase. Enrollments have grown steadily, with the expanding educational needs of adult learners compensating for the temporary dip in the number of high school graduates associated with the post-war baby boom/bust cycle. Yet the costs of providing education, research, and service have also grown—even faster, in fact, since these university activities depend upon a highly skilled, professional workforce (faculty and staff), require expensive new facilities and equipment, and are driven by an ever-expanding knowledge base.

Even as the demand for educational services has grown and the operating costs to provide these services have risen, public support for higher education has flattened and then declined over the past two decades. The growth in state support of public higher education peaked in the 1980s and now has fallen in many states, in the face of limited tax resources and the competition of other priorities such as entitlement programs and corrections. While the federal government has sustained its support of research, growth has been modest in recent years and is likely to decline as discretionary domestic spending comes under increasing pressure from federal budget-balancing efforts. There has been a significant decline in federal financial aid programs over the past two decades, with a corresponding shift from grants to loans as the predominant form of aid. While increasing tuition levels have provided short-term relief, it has also triggered a strong public concern about the costs and availability of a college education, along with growing forces to constrain or reduce tuition levels at both public and private universities.

It seems increasingly clear that the higher education enterprise in America must change dramatically if it is to restore a balance between the costs and availability of educational services needed by our society and the resources available to support these services. The current paradigms for conducting, distributing, and financing higher education simply cannot adapt to the demands and realities of our times.

Societal Needs

The needs of our society for the services provided by our colleges and universities will continue to grow. Significant expansion will be necessary just to respond to the needs of a growing population that will create a 30 percent increase in the number of college-age students over the next two decades. But beyond this traditional role, we should recognize the impact of the changing nature of the educational services sought by our society.

Today's undergraduate student body is no longer dominated by eighteen to twenty-two year old high school graduates from affluent backgrounds. It is comprised as well of increasing numbers of adults from diverse socio-economic backgrounds, already in the workplace, perhaps with families, seeking the education and skills necessary for their careers. When it is recognized that the magnitude of this need for higher education may be significantly larger than that for traditional undergraduate education, it is clear that either existing institutions will have to change significantly or new types of institutions will have to be formed. The transition from student to learner, from faculty-centered to learner-centered institutions, from teaching to the design and management of learning experiences, and from student to lifelong members of a learning community, all suggest great changes are ahead for our institutions.

In the current style of "just-in-case" education, we expect students to complete degree programs at the undergraduate or professional level long before they actually need the knowledge. We are beginning a shift in demand to "just-in-time" education in which education is sought when a person needs it through non-degree programs and to "just-for-you" education in which educational programs are carefully tailored to meet the specific lifelong learning requirements of particular students. There is also a shift from synchronous, classroom based instruction to asynchronous computer-networked based learning and the provision of ubiquitous/pervasive learning opportunities throughout our society, which will demand major change.

Technology Drivers

As knowledge-driven organizations, it is not surprising that colleges and universities should be greatly affected by the rapid advances in information technology—computers, telecommunications, networks. This technology has already had dramatic impact on campus research activities, including creating an entirely new form of research: computer simulation of complex phenomena. Many of our administrative processes have become heavily dependent upon information technology—as the current concern with the approaching date reset of Year 2000 has made all too apparent. There is an increasing sense that it will have an even more profound impact on the educational activities of the university and how we deliver our services. To be sure, there have been earlier technology changes such as television, but never before such a rapid and sustained period of change with such broad social applications.

Of most significance here is the way in which emerging information technology has removed the constraints of space and time. We can now use powerful computers and networks to deliver educational services to anyone at anyplace

and anytime, no longer confined to the campus or the academic schedule. The market for university services is expanding rapidly, but so too is competition. New organizations such as virtual universities and "learning-ware" providers are entering this marketplace to compete with traditional institutions.

Restructuring

As a result of these pressures, higher education is likely to evolve from a loosely federated system of colleges and universities serving traditional students from local communities into, in effect, a knowledge and learning industry. Since nations throughout the world recognize the importance of advanced education, this industry will be global in extent. With the emergence of new competitive forces and the weakening influence of traditional regulations, higher education is likely to evolve like other "deregulated" industries, e.g., health care or communications or energy. In contrast to these other industries, which have been restructured as government regulation has disappeared, the global knowledge industry will be unleashed by emerging information technology, which releases education from the constraints of space, time, and certification monopoly.

Will this restructuring of the higher education enterprise really happen? If you doubt it, just consider the health-care industry. While Washington debated federal programs to control health-care costs and procrastinated taking action, the marketplace took over with new paradigms such as managed care and for-profit health centers. In less than a decade the health care industry was totally changed. Today, higher education in America is a \$180 billion a year enterprise. It will almost certainly be "corporatized" similarly to health care. By whom? By state or federal government? Not likely. By traditional institutions such as colleges and universities working through statewide systems or national alliances such as AAU or ACE? Also unlikely. Or by the marketplace itself, as it did in health care, spawning new players such as virtual universities and for-profit educational organizations? Perhaps. Just note a brief passage from a recent venture capital prospectus analyzing possible investments in education:

"As a result, we believe education represents the most fertile new market for investors in many years. It has a combination of large size (approximately the same size as health care), disgruntled users, lower utilization of technology, and the highest strategic importance of any activity in which this country engages. . . . Finally, existing managements are sleepy after years of monopoly."

The Important Role of the National Science Foundation

Over the past half-century, the National Science Foundation has been a major force in creating both the paradigms for the research university and for graduate education.

Today, during a time of great change in higher education, the NSF's role becomes even more important both to sustain and to shape the types of educational programs and institutions most needed by our society. It can play this role in a variety of ways:

- The NSF continues to be a major patron of graduate education through its programs of research grants (research assistantships), graduate fellowships, and graduate traineeships.
- It can collect data to enable a better understanding of key issues, e.g., longitudinal studies of the careers of NSF-supported graduate students to learn how many end up in research or other fields.
- It can encourage experiments both at the national and institutional level aimed at exploring different educational paradigms.
- Through its involvement, it can provide the credibility necessary for institutional change.
- It can support ongoing dialogues on concerns and key policy issues such as those conducted by the GUIRR over the past several years.

A Possible Approach for the National Science Board

The National Science Board may have an important opportunity to not only guide the National Science Foundation's role in graduate education, but to help shape federal policies concerning this critical activity. Let me suggest several questions the National Science Board might wish to consider in their effort to respond to the White House request:

1. What is the purpose of graduate education in science and engineering?

- To produce the future researchers needed by our nation? Clearly, the current system of graduate education does this quite well.
- To produce the future faculty needed by higher education? Many suggest that the current graduate education paradigm of the research university does not serve well the majority of colleges and universities, which place far more emphasis on teaching than research.
- To produce the next generation of scientists and engineers? Note that this is a quite different mission than producing researchers.
- To provide the educational background needed for other key professionals in areas such as medicine, business, and law? There is a sense that an increasing number of students with advanced training in science and engineering are moving into other professional careers such as medicine, law, and business. Should our graduate programs be responsive to this?

- To provide the labor necessary to sustain the research university through graduate research or teaching assistantships? Unfortunately, the size of many graduate programs in science and engineering seems to be determined less by national need or employability than by the graduate assistant needs of local research projects or instructional programs.

2. *How appropriate is the current graduate education paradigm for this role?*

- The current graduate education paradigm can be characterized best as an apprenticeship (although some graduate students would suggest more of a feudal system of indentured servitude), in which the dissertation advisor has significant responsibility for not only the content but as well the duration of the program. Is there a need for better national standards to guide this system, e.g., constraints on time-to-degree?
- The current system, stressing specialization and depth of investigation, is frequently accused of cloning the current cadre of research faculty. Is there a need for greater breadth? If so, then how could it be achieved? Through a broader graduate curriculum? Through a requirement of major-minor specialization similar to that characterizing many undergraduate programs?
- Would graduate students benefit from an off-campus internship experience in industry, government, or a different type of educational institution as a part of their graduate education?
- Should there be a more strategic effort to identify postdoctoral appointments as a part of graduate education?
- Should experiments be encouraged with very different graduate education paradigms? For example, one might consider a phased, fixed-term-to-degree program that acknowledges that most graduate students will find themselves in non-research careers, e.g., faculty positions in non-research colleges and universities, management positions in industry, or policy positions in government. To this end, graduate education might consist of three phases: The first phase would be a one to two year masters degree that would provide the technical background that some students seek for further study in professions such as business (MBA), medicine (MD), or law (LL.D.). The next phase would consist of two more years of dissertation-based study leading to a doctorate suitable for non-research careers. Finally, the highly specialized training necessary for those few students planning to enter research-intensive careers would be obtained through postdoctoral study.

3. *What is the best way to fund graduate education?*

- Research assistantships? Clearly, this is the preference from the faculty perspective, since it provides the principal investigator maximum control over graduate students. Yet, one might well argue that the fundamental

purpose of graduate research assistantships should not be to provide cheap labor for research projects but to support graduate education. A policy statement to this effect might be appropriate.

- Graduate fellowships? This has been the traditional alternative to research assistantships, although there have been concerns. These include whether graduate fellows are too disconnected from the research interests of faculty and whether the portable nature of these fellowships tend to advantage the most prestigious institutions.
- Graduate traineeships? Note here that the principal distinction between *traineeships* and *fellowships* is that traineeship grants are made to university programs and departments for a specified purpose or program and then assigned to graduate students by the institutions. While traineeships have not been a major component of the NSF portfolio, they have been the dominant form of graduate student support in other areas, such as the health sciences, since they can allow a more carefully designed graduate experience.

4. *What is the role of the research university relative to the rest of the higher education enterprise?*

We have noted that there is an increasing sense among many that the research university, where most graduate education is conducted, is becoming increasingly detached from the rapidly changing higher education enterprise both in this country and abroad. In the past these universities have not only provided most of the faculty but most of the pedagogical models and curriculum content for higher education in America. Today, the relevance of the research university paradigm to the learning needs of our society is being seriously questioned. Most of us in the scientific community would disagree with Peter Drucker's statement this past summer: "I consider the American research university of the last forty years to be a failure. The great educational needs of tomorrow are not on the research side but on the learning side." Yet this is just the view held by an increasing number, both within the higher education community and in society more broadly.

Concluding Remarks

The research university has been extraordinarily successful in meeting the needs of our society during the past half-century. Yet today many of those needs have changed, and the role of the research university and its relationship to the federal government are being questioned.

Part of the difficulty might be traced to the absence of a federal policy for human resource development analogous to that set out in *Science, the Endless Frontier* for academic research. There has been nothing to succeed earlier federal policies such as the G. I. Bill and the National Defense Education Act. Instead the nation has allowed human resource development to occur largely as a byproduct of research programs rather than through a strategic consideration of national

needs. It is little wonder that the current system tends to replicate itself by producing scientists and engineers trained for increasingly narrow—and increasingly limited—research roles. Largely ignored are the broader interests of our best students, the increasing diversity of today's generation of students, and the complex and rapidly broadening roles in our society played by those with science and engineering training

There is an urgent need for the Administration to develop both a vision and policy aimed at providing the human resources in science and technology necessary to respond to both the contemporary and future needs of the nation. This human resources policy should be closely aligned and tightly coordinated with federal policies concerning science and technology.

The National Science Board may have the opportunity to play a significant role in helping to frame this policy in the area of graduate education in science and engineering.