Realignment of Roles of Engineering and Science in a Changing Research Environment

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Although the strength of the U.S. research enterprise has never been greater, it faces substantial challenges today and in the future. All indicators suggest that the future pace of federal funding for research will fall well below that of the last two decades, and it seems overly optimistic to expect industry to be able to make up a significant funding gap. Expectations also continue to increase on the part of the public and elected officials for practical outcomes that justify expenditures for research.

On the positive side, considerable attention is being given to the issues facing the nation's research enterprise. The Council on Competitiveness summarizes the situation in its report, "Endless Horizons, Limited Resources," where it is recommended that universities, government and industry increase efforts towards collaboration if the more restricted resource base of the future is to be optimized.[1]

The title of this session proposes another idea for better positioning of our research efforts: "The Symbiosis of Science and Engineering in Policies for Innovation." My dictionary defines "symbiosis" as "the living together of two dissimilar organisms in close association or union, especially where this is advantageous to both, as distinguished from parasitism." If you have been around for a while, you might remember some conditions where the words "dissimilar" and "parasitic" applied to science and engineering. However, in a world with interdisciplinary challenges that do not respect artificial boundaries, and facing a future of limited resources, tendentious efforts at rivalry are outdated. Greater collaboration between engineers and scientists is not only needed, but necessary.

Our university campuses are the nexus where large numbers of engineers and scientists have great flexibility in addressing wide ranging research objectives, and hence represent a crucial staging ground if symbiosis is to occur. Yet, universities present a special challenge in adapting to change because of their traditional emphasis on disciplinary structure, professional accreditation, and specialization.

The path forward is not simple, but is unavoidable. We must answer how engineering and science can better merge their efforts to solve problems society understands. How universities can improve their ability to work with industry, particularly the slimmed down, hard-charging new age industry that competes in a global economy. How coalitions of government, industry and universities can succeed. Finally, how to sustain a core of the well traveled and still valuable individual and curiosity-driven research.

Blurring of the Lines Between Science and Engineering

While it has taken time, the real and perceived philosophical barriers between scientific and engineering research have gradually diminished. Studies by historians of technology like Vincenti[2] and Kranzberg[3] have shown the flaws in the old assumption that engineering research only represented an application of science research. This barrier created a caste system that was not conducive to engineering and science partnerships. Today we understand research is a continuum where each discipline has a part to play at any point within the spectrum. While it is true that engineering research is typically driven by a desired practical result, and for science research this is often less the case, the lines between the two are blurring and with positive effect.

The National Science Foundation (NSF) took a major step in diminishing the separation between engineering and science with the creation of national research centers that required collaboration between engineers and scientists at universities as well as with industrial partners. Other agencies such as NASA and the Office of Naval Research have undertaken similar initiatives.

Following the old adage, "money talks," the NSF Center program used financial clout, and accountability evaluations, to insure that the center faculties had to produce on promised interdisciplinary research. Importantly, NSF required not only collaborative research, but also the creation of curricula that reflected the joint efforts of engineers and scientists. In the long run, the new curricula may be more influential than the research, because it will result in education of generations of engineers and scientists who know how to work together using a shared knowledge base.

The three 1996 NSF Engineering Research Centers include: at MIT, "Environmentally Benign Semiconductor Manufacturing"; at Stanford University, "Engineering Biomaterials"; and at the University of Southern California, "Integrated Media Systems." Although these are engineering centers, the crosscutting areas they address will require considerable science-based research and education to succeed.

In its radical restructuring of itself to address growing global competition, corporate America found it had to break through the stovepipes that tend to develop around research, manufacturing and sales. The result was elimination of the notion of "passing work over the transom," and dramatically improved collaboration across disciplinary and professional lines. Recent data showing U.S. industry today to be more productive than any in the world other confirm the wisdom of the changes that were effected.[4]

Universities today lag industry in reducing the barriers to interdisciplinary efforts although they are making progress. While realignments have occurred both in terms of philosophy and application of engineering and science, much work remains to be done.

Creating a Supportive Environment in Universities

Disciplines and professions are long established in universities by tradition, organizational and management structures, professional rankings and accreditation, and policies such as promotion and tenure. Since the clock cannot suddenly be turned back on developments that took hundreds of years to create, alternative approaches are needed to facilitate a transition to interdisciplinary research and teaching.

Positive incentives provide one of the best tools to this end, and universities can follow NSF's lead in allocating seed monies, equipment funding and personnel to encourage those units willing to cross disciplinary boundaries in both teaching and research.

Many universities have recognized the need to realign policies about promotion and tenure to allow credit for interdisciplinary work. An example of a well-meaning policy that deters interdisciplinary efforts is the process of seeking external letters of support for promotion and tenure. This has the effect of causing young faculty to specialize so they can get the requisite letters from other specialists. As long as letters of support are used, at least a broader definition of the expertise of the letter writers and the way in which information is solicited is needed. In the long run, the value of external letters of support needs to be re-examined since it is unclear any more than a minicusle percentage of promotion or tenure decisions are changed by them, while great effort is expended in collecting and writing them.

The rapid spread of interdisciplinary centers within universities has been largely positive. Yet it is important that interdisciplinary centers build upon, collaborate with, and utilize the efforts of traditional disciplines. To do otherwise is ill-advised because traditional disciplines remain the seat of most educational offerings within the university. Research cannot be separated from education, for to do so is to create a distance that can feed an anti-research sentiment.

Universities also struggle with intellectual properties rights in their research contracting processes, creating a negative incentive to university/industry collaboration. The Byah-Dole act allowed universities to keep all intellectual properties on federally funded research. Industry is not so generous, and each industry, indeed, different units within a corporation, may have different rules about intellectual properties. A more flexible approach is needed with a range of options, some of which allow for negotiation of intellectual properties downstream of the research initiation, when there is some assurance an intellectual property of value will be developed. Industry also needs to work at understanding the structure of universities and to become more flexible about university needs for publication and access to a share of intellectual property rights.

Thematic Goals with Positive Societal Outcomes

Goals for research and teaching can be defined in terms of disciplinary channels or under the larger umbrella of themes that have societal outcomes. The latter approach has the advantages of being easier to explain to the lay public and promoting collaboration between engineers and scientists and others. It also provides the means to utilize the efforts of campus disciplinary strengths by focusing on larger objectives. This targeting does not take away from the disciplines, but rather collects campus energies for larger institutional and societal objectives. It also does not imply that the thematic areas of research should be the only ones pursued, allowing flexibility of choice for those who wish to investigate other issues.

There are many examples of thematic goals, some of which require more emphasis on engineering, and others on science. The Clinton administration budget for research in FY 96, amounting to a total of $7.8 billion, identified six priority areas in terms of interdisciplinary initiatives. Examples included: Technology and Learning; High Performance Computing; and Partnership for a New Generation of New Vehicles.

Other umbrellas for research and teaching initiatives are manufacturing, biotechnology, telecommunications and sustainable technology. Manufacturing is a subject that relies more on engineering than scientific research, but there are major roles for science-based research as well. Georgia Tech is fortunate to house the NSF Center for Electronic Packaging, a center devoted to research in support of the consumer electronics industry and the manufacturing of these products. The theme of the center is easy to understand since it relates to assisting U.S. industry in its efforts to remain competitive in consumer electronics. Yet the research conducted required is at the cutting edge of both science and engineering relating to development of the means of creating powerful multi-chip assemblages.

Thematic goals for research and teaching can be reinforced through incentives to units willing to develop the collaborative research teams needed to do the work. This can extend to facilities. On campuses, physical proximity for the engineers and scientists who work on the research is helpful. Construction or renovation of buildings, or creation of complexes, can be designed to allow for co-locating multidisciplinary teams of engineers and scientists. A visit to almost any research university today will show the newest buildings dedicated to such activities. In some cases this even involves co-location of industry with academic researchers.

Research Coalitions between Universities, Industry and Government

There is general agreement that the most effective use of the funding that will be available in the future will be obtained through coalitions of universities, industry and government working together. Yet, this approach is not without difficulties and it requires careful strategy to make it work. Successful examples have certain common characteristics:

1. Focused efforts with strategically limited objectives
2. An appropriately designed incentive structure
3. A limited number of key partners with a will to work together
4. A base of steady funding that drives the core research
5. Robust communications systems between partners
6. A lean administrative team

Even with these elements, leadership and political skill are needed in ample supply to address the day to day issues that inevitably arise, and which if not addressed will destroy the goodwill needed to make the coalition work. The individual charged with managing the coalition and its partnerships needs savvy, political and social skills, an understanding of all of the cultures involved, and a high energy level. The demand for such individuals is strong and the supply thin. This may pose a special opportunity for some of our nation's innovative business schools.

A successful example of a coalition at the national level is the National Textiles Center which is funded by a federal contribution and support from the textiles industry. Universities are the research vehicle, working in cooperation with the government and the member industries. The textiles industry, having gone through a shakeout in the 1980s, has largely retooled itself into a high tech industry in part using the research coming from the National Textiles Center. The universities that are part of the Center do the research, with research themes chosen by a technical advisory board composed of industry, government and university representatives. Challenges to the Center have come recently from threats to cut off the federal funding base, but to date this has not occurred.

At the state level, the Georgia Research Alliance has proven a successful model of strong coalition which is directly impacting the economy of Georgia. The State of Georgia provides base funding for research from lottery receipts and the research is conducted by the six research universities in Georgia, four public and two private. The research is focused into three thrust areas, biotechnology, telecommunications and environmental technology. In addition to funding for projects, funding is also provided for hiring of eminent scholars to lead the research efforts. This brings senior leadership, often directly from top industry or government agencies, to help guide the research and strategic use of funds.

To obtain research support, the work has to be approved by a government/industry board, and conducted with at least one other university partner in the Alliance. Chances for funding are optimized by showing potential for leveraged support by private industry or the federal government. To date, the state has provided $125 million and the universities have leveraged this to obtain over $300 million in external contracts. Research funding in the Alliance grew from $400 million in 1993 to $700 million in 1996. The Alliance has been successful in helping attract industry to the state using an innovative venture capital approach and by working cooperatively with the Georgia Department of Industry and Trade. This has helped garner political support for the Alliance.

A Balanced Support Portfolio

The funding challenges faced in the future will lead to changes in the way business is done. As the changes are instituted it will be important to have a system to insure balance is maintained in the nation's research support portfolio or we risk losing key elements that make for a robust research environment. A recent article Smith and McGeary[5] makes this point well. They cite the example of the increased support for NIH funding in the last congressional session. While this was welcomed, the decision was isolated and ran the risk of coming at the expense of other R&D funding, even work that might be critical in support of NIH efforts.

The portfolio concept also needs to insure the proper balance between team-oriented, industry related research and work by individuals and curiosity driven-research. It is often the solitary investigations of narrowly defined issues that result in the most dramatic advances. A field like nanotechnology, once only the province of a few researchers with the vision and curiosity to understand the fundamentals of molecular-sized entities, laid the foundation in this field. Today, nanotechnology has emerged as a powerful tool for a wide range of potential practical developments. Within the context of the new era of research, the opportunity for individual researchers to pursue curiosity driven studies needs to be maintained.

Conclusions

Dynamics driving the need for symbiosis of engineering and science research and teaching come from the recognition of the interdisciplinary challenges society faces and the on-going reduction of federal support for research. University campuses present special challenges in making changes because of their traditions, organization, and professional accreditation processes. Yet they offer the potential of great return on investment for the effort required.

Recommendations to assist in making the necessary transitions include:

1. Continue to blur the lines between basic and applied research and engineers and scientists to allow their respective efforts to be blended to optimize the limited research funding of the future.

2. Provide greater purpose to our research and teaching efforts using themes that resonate with the public and which allow campus disciplinary energies to be focused.

3. Create a positive campus environment for collaborative research and teaching; this requires a deliberate strategy designed in partnership with faculty and the traditional disciplines.

4. Develop well-designed coalitions between universities and industry and government to address targeted issues which can be shown to have societal payoff within an acceptable time frame.

5. Provide a system of checks and balances to insure the federal government has a balanced portfolio of research support.

References

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