THE PROFESSOR AS RESEARCHER IN TODAY'S ENGINEERING RESEARCH ENVIRONMENT

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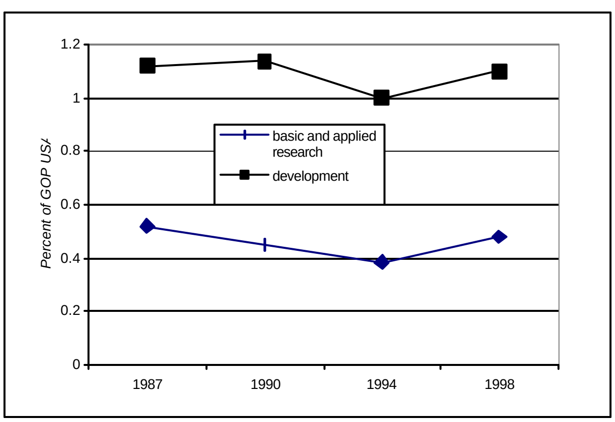
Abstract – *Engineering research has been most affected by four important factors: (1) engineering research has become more highly competitive, (2) the need for engineering solutions has never been greater, (3) internationalization of markets – as well as problems and issues – is escalating, and (4) the speed and capability for fluency of communication is increasing. This paper considers factors in faculty relationships with international research and development entities. Researcher relations with those who provide research funding, including business and industry, government agencies, and private foundations, need now to be increasingly tenacious. The quality of proposed research is of highest importance in successfully acquiring funding. The professor also needs to consider the development of skills in communicating fluently about accomplishments and plans, interacting effectively both professionally and socially with diverse constituencies, and delivering reports and products successfully, on time, and on budget. Some of the skills to develop clearly include effective communication of ideas, planning and resource management, administration and supervision of multi-cultural working teams.*

Index Terms – engineering, funding, professors, research

RESEARCH AND DEVELOPMENT ESCALATE AS A UNIVERSITY ENTERPRISE

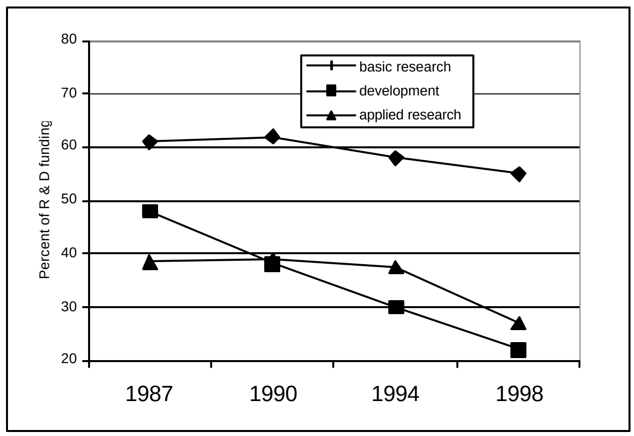
Competition to produce research and development solutions has become global in scope, with an emphasis on the productivity of research universities. As industries continue

FIGURE 1
FOCUS OF U.S.A. INDUSTRY R & D



to reduce the amount they can spend on research requiring long term investigation and that is curiosity-driven, they are increasingly turning to the academic sector to assist in this role. Recent data (Figure I), show that business sector expenditures for basic research are low as compared with spending on product development [1]. Figure II shows the relative decline in federal commitment to research and development [2].

FIGURE 2
U.S. FEDERAL COMMITMENTS TO RESEARCH AND DEVELOPMENT



Rita Colwell, Director of NSF, reported a decline in the relative federal share of R & D expenditures from 60% in 1969 to 27% in 1999. The balance of R & D funding is industry-based. The implications for the university sector are threefold:

- Faculty have a greater opportunity to be more heavily involved in research activity as a proportion of actual workload and there is an expectation for this to increase.
- Faculty, particularly engineering faculty, have greater opportunities to contribute to solutions of industrial, environmental and social problems than they formerly did.
- Faculty are developing new skill sets that go beyond traditional research to include more active relations with business and industry, government funding agencies, and foundations.

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There are important consequences associated with these changes and these require the attention of faculty and more generally, universities.

NOTABLE CHANGES AT THE UNIVERSITY

University R & D research expenditures are increasing annually (National Science Foundation). We can see implications for the nature and quality of activities that faculty are engaged in, the introduction of new influences and colleagues from business and industry, and subsequent positive effects that these factors can have on instruction of students. We can also make some comments on new rewards that are available to faculty.

Joint R & D

Important changes related to the growth of R & D at universities can be found in numerous indices of university relations with the business, industrial and government sectors. The volume of joint R & D has increased. There are many projects that involve an industry-government-research university partnership. At NJIT, for instance, we are currently engaged in research with Lucent Technologies and the United States Army involving communications. These are particularly satisfying projects, and often involve the participants in very advanced development applications.

The University as Laboratory

Faculty are bringing real projects into instructional laboratories. This has altered instructional strategies and has improved education by giving students hands-on experience with meaningful problem solving activities, thus educating in context. Furthermore, we have seen a shift in engineering education that incorporates project-based learning exercises into the curriculum at the very beginning of the education of an engineer rather than later on. We are finding that rather than saving courses stressing synthesis across discrete areas of learning for the final years, the concepts involved should be introduced earlier to capture the attention of the student. This has been very effective in improving the relevance of the material for students, in providing them with active, participatory learning experiences, and in giving them a better introduction to real-world problems. NJIT has conducted research on learning outcomes that demonstrated that these instructional strategies are very successful in improving academic performance, student retention, and graduation rates [3].

Incubators

Research universities are mounting greater numbers of business incubators. This involves university-driven development and support of entrepreneurial, growth businesses. The contribution of universities in this arena can not be overstated – faculty and students become involved in the process of making entrepreneurial efforts work. Entrepreneurs use university facilities. Universities often benefit by sharing technically in the fruits of business activities.

RESEARCH AND THE ROLE OF THE PROFESSOR

As Figures I and II illustrate, both business and industry funding and government funding tends to focus on specific applications, and business interest is primarily on product improvement and ultimate profitability in markets with new performance criteria and demands. Research which is currently most funded includes:

- Product-driven R & D
- Mission-oriented R & D
- Emphasis on D

Government-funded projects, similarly, emphasize those projects with measurable outcomes that change and improve economic, environmental, educational, defense, and/or other social factors. There is a strong emphasis, therefore, on research with meaningful and measurable outcomes.

Accountability

The nature of development projects of these sorts require that faculty work well with applications- and mission-oriented colleagues coming out of environments that are appreciably different from those traditionally associated with academia. Some of the differences amount to important culture differences, with potential to impact relationships. Chief among these are the level of accountability for timeliness and applicability and efficacy of products that are typical in the business and government environment. Faculty need to demonstrate an equal concern for these accountabilities in order to thrive in the relationships in order to ensure ongoing support.

This is likely to require development of managerial skills. The faculty researcher needs to have, in his or her toolbox, good project management skills. This includes good record-keeping and accounting practices, ability to manage research staff, ability to delegate appropriately, time-management skills, and excellent communication skills. In addition, faculty need to be able to spot weaknesses in the project and solve management problems as well as scientific problems.

Work Across Cultures and Disciplines

Another important quality associated with the current array of R & D projects is the multidisciplinary nature of the research. Interests that emanate from both business and the government often influence product development from the outset. Marketing concerns are apparent early on, for instance, in new product development. Both government applications and product development projects more generally need to consider global factors, such as global markets and resources, from the outset of development. Furthermore, it is probable that specialists from a number of scientific disciplines will be needed in order to bring the project to a productive conclusion. Faculty researchers need to consider development, production, marketing and distribution and all of the sciences that contribute to those fields.

Research results, whether disclosed in a professional meeting or published in scientific or engineering journal, are at once available globally, Meetings are located in less developed nations as well as in world capitals. While the results of engineering research may be actualized more rapidly in developed nations, the sophistication of faculty is everywhere increasing. The engineering faculty member now plays on an international stage rather than solely in the regional, or even national arena. Many projects will reflect multi-national concerns and will include international players in the funding, research and development, application and promotional aspects of the work. Faculty, therefore, must be able to work well and successfully across multi-national cultures as well as across scientific disciplines.

The development of engineers as researchers is a topic we dealt with in great detail last year at the annual ICEE conference. The statements we made then, with regard to the complete education of the engineering student, are no less true for the adequate preparation of faculty to operate in this new landscape. Faculty must be broadly prepared to have knowledge of diverse sciences, diverse cultures, and management and communication skills.

Promoting a Healthy Economic Environment

Good research and a high level of university participation in research are tied to healthy economic development. We have come to understand the need for *clusters of innovation* that include government, business and university participants

A regional economy represents a unique mixture of clusters that allow engagement with the world outside at a level that is sufficiently sophisticated to be global in reach. Clusters of innovation optimize crossovers among industries, research universities, and their various service providers. In many regions of the United States, and quite deliberately, clusters of innovation are being developed with emphasis on the productive relationship of industry, government and research universities and with the clear objective of building new companies and generating new jobs - higher paying jobs than the average, and new companies to replace those that inevitably fail.

Innovation is created, not inherited. Michael E. Porter and Duane Ackerman of the National Council on Competitiveness recently conducted a survey of 200 business and civic leaders in five metropolitan regions (Atlanta, Pittsburgh, Raleigh-Durham, San Diego and Wichita) to pinpoint factors in business success. They found that the key differences between "good" and "poor" regions include:

- Access to skilled labor and qualified scientists and engineers
- Proximity to regional research and development centers
- Transfer of knowledge from research institutions
- Linkages between firms and organizations in the region

The study of clusters has established that universities are pivotal to innovation and economic development. Experience teaches that in particular a special type of university, the scientific technological research university (schools like Carnegie-Mellon, Georgia Tech, MIT, NJIT and UNC-Raleigh) is critical to forming and sustaining a cluster. Schools, such as these, share a primary goal to educate engineers, scientists and managers for a wide variety of businesses and careers and their central mission is to create, promote and advance technology and science. They are the natural home for business incubators, like NJIT's Enterprise Development Center, which has launched over 50 successful new high-tech firms.

There is therefore a social and cultural dimension to the participation of faculty which probably needs to be described as political. Faculty are encouraged to explore concepts of research and development centers that work hand-in-hand with business and government interests. Faculty need to support this concept, and bring their influence to bear on supporting these developments.

Competition

Competition to obtain research funding has increased as a consequence of the high quality of faculty-researchers globally as well as nationally, and because of the increased pressure on universities to produce quality research that contributes to the economic and social well-being . There is also a wider understanding of the role of university research to the economic and social well-being of regions, states, and nations.

The primary ingredient for successful competition is good ideas. Research talent is the best foundation for winning funding. However, there are many other skills and talents that now come into play, and the professor who is well equipped in new ways will enhance his or her competitive edge. I am proposing three main areas in which the researcher must reach an excellent level of performance which are not strictly science.

First, the new tools for communication are among the most important to be mastered. Because of the speed and fluency that can be obtained with today's electronic communication, the researcher who does not have these tools available will flounder before those who do. One can reach funders quickly, and with the clearest and most clearly defined product, only through electronic media.

Secondly, tenacity matters. It is not enough to initiate relationships and initiate contact. In order to succeed, the researcher has to follow-up and persist. This is an attitude as well as a skill set. The researcher must project a "can-do" attitude as well as a "will-do" approach. Proposals must be submitted as often as it takes to get it right and get it funded. Interpersonal relations must be tended to, and the researcher must acquire the trust, and whenever possible, the loyalty of agencies, businesses and foundations that fund research.

Third, the researcher needs to be a strategic planner and a strategic thinker. This relates to thinking about the substance of the research, the management of research projects, and the development of funding sources and resources.

WHO WILL DO LONG-TERM RESEARCH AND HOW WILL IT BE FUNDED?

Important issues arise regarding the funding of curiosity-driven research on the one hand, and R & D on the other. It is the long-term, curiosity-driven, more theoretical and speculative research that is most likely to need additional funding. Significantly, we know that reductions in this type of research have long-term and negative implications for the ultimate health of development and applications-based research. The greatest economic health has been associated with a high degree of theoretical and long-term research, which often provides profoundly important underpinnings for subsequent applications.

SUMMARY OF IMPLICATIONS FOR PROFESSORS

The new research environment produces a broader spectrum of intellectual and professional work for the faculty member. The challenges are great, but the environment also creates the opportunity for a fuller, richer, more diverse professional life, and holds out the prospect for great rewards. Good research can have great positive, transforming effects.

There are also new challenges and many changes that characterize successful work by faculty in today's research environment. In addition to developing lines of original and meaningful research inquiry, faculty need to:

- Show energy and tenacity in creating funding opportunities, and that includes identifying opportunities and preparing research proposals.
- Recruit and work effectively with a diverse group of scientists and other specialists as part of the research team
- Work well across international boarders, with participants and cultures diverse from one's own
- Manage the operational components of complex research projects, including laboratory facilities, diverse staff, students participating in research projects, budgets, and technical infrastructure needed to conduct research
- Frame research in terms of outcomes to focus the purpose of the research, and to prepare to report on findings in a way that is clear with regard to consequences and effects
- Master modern tools of communication, research and instruction, especially the internet and powerful tools of presentation and communication for communication with team members and with funding agencies

SUMMARY OF IMPLICATIONS FOR THE UNIVERSITY

The university must be prepared to support faculty in the development and successful use of these new skills. At NJIT, for instance, we conduct workshops in the use of new technologies, and provide help in identifying funding opportunities, as well as in grant preparation. It is critical, however, for the university to provide a good playing field for its faculty by building the reputation and public recognition for the university. It is important to encourage and participate in activities that enhance the visibility of the accomplishments of the university and its faculty.

REFERENCES

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