Growing the National Innovation System: Reshaping Professional Graduate Education to Ensure a Strong U.S. Engineering Workforce

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Abstract

This is the first paper in the special panel session on reshaping graduate education to better serve the needs of the practicing profession in industry to ensure a strong U.S. engineering workforce for competitiveness. The newly established National Collaborative Task Force of the Graduate Studies Division of ASEE is taking a key leadership role to enact major reform in graduate engineering education at the national level to spur U.S. technological innovation, unleash industrial creativity, and enhance competitiveness. This paper addresses the national urgency for reform in higher education to strengthen U.S. innovative capacity and outlines purposeful action that needs to be taken in transforming graduate education to better meet the needs of engineering practice for leadership of technology innovation. Further, it defines a road map for change to help guide the reshaping of professional graduate education as a "system for lifelong learning" that is specifically designed to support the continuous development of technology in industry and to grow the nation's engineering graduates as technology leaders in industry simultaneously.

1. Introduction

Because of the urgency to strengthen U.S. innovative capacity for economic development and the nation's security, the U.S. Science and Technology national innovation system and the nation's system of graduate engineering education are in transition. While increased efforts must be undertaken to ensure the supply of domestic graduate students for academic research and teaching positions at the nation's research universities, accelerated efforts also must be undertaken to better ensure the further graduate development of a strong U.S. engineering workforce in industry responsible for leading the process of engineering for creating, developing, and innovating new technology for competitiveness.

The National Collaborative Task Force was established in 2001 as an initiative of the Graduate Studies Division of ASEE to meet the need for transformation. The purpose of this paper is to help awaken the sense of urgency for government, industry, and universities to work together in reshaping professionally oriented graduate education to strengthen the creative, innovative, and leadership capacity of the U.S. engineering workforce for competitiveness. The task force is taking a key leadership role at the national level in reshaping graduate education to better serve the needs of engineers in industry and to better support the nation's industrial infrastructure for advanced technology development. The task force has studied the issues associated with the status of U.S. engineering education; the resulting "educational gap" that has limited the further graduate development of the engineering workforce contributing to a decline of U.S. competitiveness over several decades; and the national impact that purposeful reform in graduate education can make in ensuring a strong U.S. engineering workforce to enhance the nation's economic development and national security.

2. The Urgency of Reshaping Professional Graduate Education To Strengthen U.S. Innovative Capacity for Competitiveness

U.S. competitiveness is heavily dependent upon the further graduate development of our domestic engineers who are the nation's primary intellectual capital in leading the process of engineering for creating, developing, and innovating new technology in industry. These working professionals are the lifeblood of U.S. competitiveness. However, there is a growing shortage of engineering-leaders in the national innovation system who can assume responsible leadership to sustain the nation's technological thrust in the technology-driven economy. During the past decades, emphasis in U.S. engineering graduate education has focused primarily on preparing graduate students as future scientists for academic research/teaching positions at the nation's universities. But, a balanced emphasis during this same time period was not placed on the further graduate development of the nation's engineers in industry for technology development. Yet, less than 10% of U.S. engineers are engaged in scientific research. As Gary, former vice president of engineering at General Electric, pointed out to ASEE several years ago: technology development is the primary function of engineers in industry.[1]

But most of U.S. engineering graduate education still emphasizes research which results in the disconnect that has existed between graduate engineering education and practice for several years. As a result of the unbalanced focus, industry has identified numerous competency gaps in the education and underdevelopment of our technological resource in engineering. And the nation has paid accordingly throughout the years in the loss of its innovative capacity in too much of U.S. industry resulting in the loss of jobs and America's competitive edge. The demand for a strong U.S. engineering workforce with the critical skill-sets, knowledge, and professional experience required for growth from entry-level engineering through executive engineering levels for leadership of constant technology innovation in industry is forcing the need for a sweeping transformation in engineering graduate education. The need for reform affects the nation's future technological infrastructure and corporate culture for innovation from aerospace technologies,[2] to automotive technologies, to chemical technologies, to medical technologies, to textile technologies, to energy technologies, etc., and to new U.S. technologies yet created. The urgency for reform in engineering graduate education is two fold.

- First, a crisis is occurring in the U.S. engineering workforce in industry and government service. A significant percentage of the experienced engineering workforce will retire in the next few years with the potential loss of America's competency base in trained graduates who are experienced in the conceptualization, development, and leadership of creative technology development and innovation.

- Second, the process of engineering for purposeful technology development has changed. And the conventional academic perception portraying that the majority of technological developments arise from [Basic Research] → [Engineering] → [Technology] as a linear process resulting in the form of new/improved products, processes, systems, and operations is incorrect and is outmoded for ensuring economic growth and U.S. competitiveness or in ensuring continuing, deliberate systematic advanced technological developments for our national security.[3,4]

Although the United States has achieved preeminence in research-based graduate education and has developed a strong U.S. scientific workforce, at the nation's research universities and government laboratories, it has neglected the fullest professional graduate development of a strong engineering workforce in industry during this same time span largely because of the flawed belief originating in 1945 U.S. Science Policy [5] that the majority of technology developments flow primarily from basic research. Although scientific research is important to gain a better understanding of phenomenon, technology is the engine for economic growth; and technology development is now viewed as a deliberate creative process of engineering — driven by real-world needs — that is supported by directed scientific research. [6,7]

3. Vision: Professional Graduate Education as a "System for Lifelong Learning"

As Wm Wulf, president of the National Academy of Engineering, pointed out to the 2002 Annual ASEE Conference, there is an urgency for reform in engineering education to reflect the process of engineering for creating technology.[8] This reform is not limited to K-12 or undergraduate education. It extends throughout the graduate's professional career in industry. The national innovation system is composed of both the nation's scientists and its engineers. Today, the U.S. engineering workforce is a cornerstone of the nation's thrust for creating technology for U.S. competitiveness. And the process of engineering for the nation's continued technological development is heavily dependent upon the continued graduate development of the creative, innovative, and leadership capacity of the engineering workforce in industry, which is subsequently dependent upon the nation's system of engineering graduate education.

But, engineering education cannot meet all of the needs, critical skill-sets, knowledge, and experience required for career-long growth within the standard four-year curriculum. Major educational reform is needed that purposefully develops professional education as a "system for lifelong learning." No longer can the nation afford to view the education of U.S. engineers to be limited to basic preparatory education at the entry-level or to the perspective that everything an engineer needs to know can be accomplished solely by formal education without experience. The call for change in engineering graduate education is neither new nor without conceptual basis.[9, 10,11,12,13] But the time lag for taking action and overcoming academic resistance for purposeful educational improvement through the professional master's and doctoral levels has proven to be too long. The American Society of Mechanical Engineers (ASME Policy Board-1971) made the call for change over three decades ago by their analysis that:

> "A prominent feature of post-baccalaureate education in mechanical engineering since World War II has been the large increase in the number of research-oriented doctoral (usually the Ph.D.) degrees granted. The research orientation provided by most Ph.D. programs has been of pivotal importance in the development of strong, well-educated faculties and in the production of highly qualified research personnel. It will be important to maintain this degree for these purposes … However, a new need has emerged for a different broadly educated graduate than is often provided by a research-oriented Ph.D. program and one who has greater depth than a graduate at the master's level. This need may be met by doctoral level programs having a strong design element. A degree of Doctor of Engineering may be granted if the institution does not wish to award the Ph.D. for such work. These programs will emphasize design or creative activities (as opposed to an intense research effort Ph.D.), considerable breadth of in-depth course work, perhaps including some humanities and economics, and significantly greater industrial involvement than has been general academic practice to date. Quality and status equal to those of the now-predominant Ph.D. (or ScD) must be maintained in the evolution of professional doctoral degrees."[14]

New models for professional master's and doctoral education are needed, integrated with creative practice in industry, to nourish the further graduate development of the nation's creative talent in engineering to the highest leadership levels of engineering practice. These models must be designed differently from conventional graduate models for academic research, and developed in the context of engineering for the continuing development of technology. They must reflect and support the critical skill-sets, knowledge, and responsibilities required beyond entry-level in engineering practice for engineering leadership of creative technology development. Today, we must no longer think of graduate education and research as synonymous. All too often, universities have viewed educational change as implementing new academic programs to fit into their existing research-oriented departments, with business as usual. This is not what the National Collaborative Task Force proposes. We propose a new vision of professional graduate education: one that will provide U.S. engineers opportunity for further professional graduate study, not in the traditional sense, but as a new "system for lifelong learning" that enables continuous professional growth throughout the engineer's professional career in industry.

4. Road Map for Change

The National Collaborative Task Force has defined a road map for change to guide the transformation as a collaborative partnership with industry/government stakeholders. The road map involves five primary milestones for substantive reform:

(1) Establish the sense of national urgency for reshaping professionally oriented graduate education that further develops the U.S. engineering workforce for effective engineering leadership of constant technological innovation in industry to strengthen U.S. competitiveness and national security.

(2) Identify the needs, critical skill-sets, knowledge, and experience that is required beyond entry-level undergraduate education for further professional graduate education of the nation's engineers in industry and government service who are assuming increasing responsibility for engineering leadership of technology development from creative problem-solving, technical program making, technology policy making, through executive engineering levels of technology leadership.

(3) Define a framework for integrated professional graduate education that combines on-going engineering practice for technology development with relevant graduate studies and experiential learning, as a matrix for graduate development correlated with the skill-sets, knowledge, and experience required beyond entry-level as a "system for lifelong learning" through the professional master's, doctoral, and fellow levels of professional competency.

(4) Identify institutional obstacles and resistances to transformation; develop an innovative strategic plan for effective change; and conceive new organizational structures for professional graduate education where learning, engineering creativity, professional scholarship, innovation, and engagement with industry flourishes to develop and sustain high-quality professionally oriented graduate programs.

(5) Implement innovative pilot demonstration model-programs (by building upon already proven successes, best educational practice, and the gathering momentum of pioneering programs) in collaborative partnership with industry and government to foster local/regional/statewide clusters of technological innovation and engagement in integrated professional graduate education for replication, continual improvement, and transfer, across the country.

5. Conclusions and Recommendations: Leading Purposeful Change

Today, the United States must maintain preeminence in engineering to be the global leader in the 21st century for technological innovation. But this can only be achieved through proactive government policies, industrial investment, and university leadership that will support the fullest professional graduate development of the domestic engineering workforce in industry as a national priority. Clearly a disconnect has existed between engineering graduate education and the needs of the U.S. engineering workforce over the last decades. Today, there is a heightened sense of urgency in reshaping relevant professional graduate education to ensure a strong U.S. engineering workforce for the nation's continued economic development. The National Collaborative Task Force recommends that the United States boldly pioneer a new frontier in professionally oriented graduate education to better develop its infrastructure in technology as the nation has done in the past in developing its infrastructure in science and research-based graduate education. Because of the importance that engineering education serves the nation, the National Collaborative believes that accelerated support must be provided the nation's universities to develop new types of innovative graduate programs that better serve the U.S. engineering workforce for competitiveness. Toward this objective, the National Collaborative is taking a primary role for leading this transformation at the national level. It is initiating the first four steps in enacting national reform, which requires further collaborative partnership with U.S. industry and government to execute and sustain this bold vision into the mainstream of university operations across the country.

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