Lifelong Learning for Innovation and Leadership in Engineering


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Abstract

In many ways graduate engineering education has served the U.S. well. But there is now broad recognition that it must change substantially to meet new challenges of the 21st Century. A noticeable decline in the number of domestic graduate students pursuing engineering has occurred and just under half of those who are pursuing the doctorate are foreign nationals. But the drop in Americans engaging in graduate studies in engineering is also being perceived by industry and by a growing proportion of graduate schools as a reflection of a lack of opportunity for lifelong learning and of an insufficiency of U.S. graduate education to serve the full professional spectrum of engineering. This deficiency is affecting U.S. competitiveness and the nation’s long-term capacity for innovation. The ASEE-Graduate Studies Division has established a National Collaborative to address the compelling issues for needed reform to improve more relevant engineering graduate education for the engineering workforce in industry as a complement to research-based graduate education. This paper describes the conceptual basis and impact of this reform and a call-for-action is submitted to promote this activity to improve U.S. competitiveness.

I. INTRODUCTION

If the U.S. is to remain preeminent in creating new innovative technologies through engineering to enhance its economic well-being and national defense, then the U.S. system of engineering graduate education must remain the world’s leader — and our graduate schools of engineering and technology must bear an increasingly important responsibility not only to serve as the nation’s primary generators of new scientific knowledge, originating from basic research, but also to serve as the primary developers of the nation’s engineering leaders who create new technology, new innovations and new technological knowledge through their creative engineering works in engineering practice in industry and government service.

A. Background

While the U.S. is on the leading edge of research-based graduate education for scientific research, it is on the trailing edge of professionally oriented graduate education relevant to the practice of engineering and leadership of technology development for continuous innovation. A major deficiency exists in the system of U.S. engineering graduate education for the development of the nation’s professional engineering workforce, which is affecting the nation’s innovative capacity for competitiveness. The deficiency in U.S. engineering graduate education is now being reflected in the noticeable decline in the number of domestic graduate students pursuing graduate studies in engineering where just under half of those pursuing the doctorate are foreign nationals.¹ The seriousness of the deficiency has been slow to emerge at the national level and has been masked by a U.S. Science Policy that originated in 1945.²

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B. The Problem

Today there is recognition that the U.S. Science Policy needs to be revised, that economic growth in the global economy is being driven by technology innovation that depends on engineering leadership, and that a new model for systematic engineering innovation has emerged that is far different from that put forth in the U.S. Science Policy of 1945.\textsuperscript{3,4,5} As the U.S. competes in the 21st century, we know that our primary creative human resource for the continuous generation, development, and leadership of new technology is the nation’s graduate engineering workforce in industry that in turn depends upon the U.S. system of engineering education to maintain the steady supply of engineers for entry into practice and to further the graduate development of the nation’s advanced engineering talent after entry into engineering practice. However, it has become increasingly obvious that America’s advanced engineering talent in industry has become the nation’s most underdeveloped resource for innovation and that substantial changes need to be made in U.S. engineering graduate education that better meet the graduate needs of this creative resource to enhance U.S. competitiveness.

Although numerous calls for reform in U.S. engineering graduate education have been made, limited action has been taken during the last two decades. This is because graduate programs have been strongly influenced by the availability of federal funding for basic research. The seriousness of the effects of the decline in the number of Americans pursuing graduate studies in engineering has frequently been perceived differently by research academics in the nation’s universities and by the nation’s advanced engineering practitioners and technology leaders in industry. But the fact remains that a proportionate decline in the number of Americans engaging in graduate studies in engineering, relative to foreign nationals, has occurred. However, as Barwise and Perry have pointed out: “Different organisms can rip the same reality apart in different ways that are appropriate to their own needs, their own perceptual abilities and their own capacities for action.”\textsuperscript{6}

Whereas domestic graduate enrollments have declined, vacancies have been filled quickly at many U.S. research universities by other means to attract graduate students. As the Committee on Science, Engineering, and Public Policy (COSEPUP) has pointed out: “In recent years, the number of foreign science and engineering students enrolled in U.S. graduate schools and the number receiving PhDs have risen unusually rapidly.”\textsuperscript{7} To date, with notable exceptions, many U.S. universities have tended to view engineering graduate education from their own interests as preparation for academic research and teaching, based largely on a linear research-driven model of engineering innovation that originated in the Science Policy of 1945. But today it is imperative that we adopt a more pragmatic view. As COSEPUP has pointed out:

- “If scientists and engineers are to contribute effectively to national, scientific and technological objectives, their educational experience must prepare them to do so … Although it is clear that human resources are the primary key to the nation’s strength in science and technology (engineering) we have not, as a nation, paid adequate attention to the graduate schools as a system for meeting the full range of needs for advanced talent in science and engineering. That is perhaps seen most clearly in the fact that the United States has effectively lacked human resources policy for advanced scientists and engineers.”

- “In effect, human resources have been taken for granted as a byproduct of our policies for support of research. The simplifying assumption — both inside and outside the university community — has been that the dominant function of graduate programs is to produce the next generation of academic researchers. It is time for a fuller recognition, by academics and policy officials alike of the changing way that graduate education in science and engineering contributes to the wide array of national needs.”
“Many of the job opportunities of the future will favor students with greater breadth of academic and career skills, so the universities and their partners in the graduate-education enterprise (industry and government) should therefore cooperate to broaden curricular options for graduate students.”

“The process of graduate education is highly effective in preparing students whose careers will focus on academic research. It must continue this excellence to maintain the strength of our national science and technology enterprise. But graduate education must also serve better the needs of those whose careers will not center on research.”

“There needs to be a deliberate national reconsideration of graduate education so that the open policy questions, the current information gaps, and the contemporary stresses are systematically addressed by a suitable blend of university, industry, professional society, and government. Those improvements can be made without disruption of the traditional commitment to excellence in basic research that has been, and must continue to be, a hallmark of the U.S. system of graduate education.”

II. REGAINING OUR COMPETITIVE EDGE: A CALL-FOR-ACTION

The changes that are required in the U.S. system of engineering graduate education are not to change what is but to create what doesn’t exist. As the Committee on Science, Engineering, and Public Policy (COSEPUP) reports, there appears to be a saturation of graduate students for research and far more seekers of jobs in academe and industrial basic research than there are positions available. Part of the reason for this is that the growth in academic positions has slowed, industrial sectors are undergoing restructuring in their R&D, and this trend is likely to continue for the foreseeable future.

A. Reasons for Change in U.S. Graduate Education

The decline in the number of domestic students in the graduate schools reflects deeper national issues than loss of domestic enrollments that are being filled by foreign nationals. Employment opportunities for basic research positions in industry are diminishing and high salaries are attracting engineering graduates directly into industry. The drop in the number of Americans engaging in graduate studies in engineering is also a reflection of the lack of opportunity for lifelong learning in engineering and of an insufficiency of the U.S. system of graduate education to serve the full professional spectrum of engineering, which is now affecting U.S. competitiveness and the nation’s long-term capacity for engineering innovation.

The significance of the need for transformation in U.S. graduate education is becoming more urgent. The generation of experienced engineers who have led much of the development of U.S. technology since Sputnik is now retiring. By the year 2010, the bulk of America’s domestic engineering leadership base will have retired, causing a “brain drain” and a loss in U.S. innovative capacity because our future leaders in industry and government are not being trained adequately to achieve engineering leadership positions. If America is to sustain long-term competitiveness in the global economy, then our domestic engineering workforce must be provided the opportunity for a new type of professionally oriented engineering graduate education in order to continue to learn, grow and develop throughout their professional careers in engineering practice and leadership of technology development in industry. Today, the U.S. must rebuild its innovative capacity for systematic technology development as a core competence in industry. As Morita, former Chairman of Sony Corporation, pointed out: “Knowing how to make the best use of your engineers will be the test of whether a company will succeed in the coming age.”* The stakes are too high to allow the present deficiency in the graduate development of our domestic engineering talent to continue. A national reform needs to be made in reshaping engineering graduate education that better
meets the lifelong learning needs of the nation’s engineers who lead the technology development process for continuous innovation. As Houle has pointed out: “Too few professionals continue to learn throughout their lives, and the opportunities provided to aid and encourage them to do so are far less abundant than they should be.” This is no less true than in American graduate engineering education today.

B. Paradigm Shift in the Practice of Engineering for Innovation

It is now evident that competitiveness is driven by several factors; that a new U.S. innovation system for Science and Engineering (S&E) has evolved; that the model for engineering innovation has itself undergone substantial transformation; and that American engineering graduate education must reflect this transformation in order for the nation to sustain competitiveness in the innovation-driven global economy. As Mary Good, former Undersecretary for Technology at the U.S. Department of Commerce and former president of the American Association for the Advancement of Science, pointed out in 1998: “Absolutely everyone agrees that the linear model is wrong. Policy based on it is destined to fail because it’s not reality.” As Good further noted: “The science community has argued for science policy, when all of us should have been arguing for science and technology policy … our future will depend on the ability of the nation to be innovative.” As Erich Bloch, former Director of the National Science Foundation, has pointed out: “the innovation model is not sequential, but highly concurrent and parallel … and the flow of knowledge is not unidirectional.” Today, scientific research and engineering development are no longer perceived as linear, sequential activities but as concurrent activities that complement each other. There is growing awareness that a transition in the national innovation system has occurred:

- First, fundamental changes have occurred with regard to the technological innovation process itself and a new model has emerged wherein a primary engine for global competitiveness is systematic engineering innovation responsive to market needs.

- Second, engineering innovation is a creative process that is primarily driven by marketarticulated demands and other social needs but interacts with directed scientific research to gain a better understanding of phenomena that are anticipated or that arise during the course of systematic creative technology development.

- Third, whereas the primary resource for basic academic scientific research resides within the research universities, the primary creative wellspring for world-class engineering innovation resides within the engineering workforce in industry.

- Fourth, the U.S. must maintain its preeminence in academic scientific research at the universities but it must also improve its capacity for systematic engineering innovation and leadership of technology development as a core competence within U.S. industry.

- Fifth, effective engineering innovation depends on the way in which the different components of the U.S. Innovation System for Science and Engineering (S&E) — industry, universities and government — can better interact with one another for economic development at the local, state and national levels.

- Sixth, U.S. engineering innovation depends upon the effective use of, the effective leadership of, and the effective professional engineering education of our advanced engineering talent in industry and government service; and upon the provision for high-quality graduate opportunity that promotes the further lifelong learning, growth and development of this advanced talent in engineering toward their fullest innovative and leadership potentials throughout their professional careers.
C. Unlocking the Innovative Potential of the U.S. Engineering Workforce

Today the call for change in U.S. graduate engineering education is transformational in scope because the practice of engineering for innovation has itself undergone substantial transformation. However, graduate education has neither reflected this paradigm shift nor the manner by which engineers grow as lifelong learners, creators and leaders of new technology development to meet societal needs. Whereas many distance graduate education programs have extended research-based graduate curricula to off-campus engineers in industry, graduate curricula often have not been designed specifically to match the growth needs of engineers relevant to the practice of engineering and the leadership of technology development for continuous innovation. A systemic deficiency in graduate engineering education exists across the nation. Because of this deficiency, the nation’s graduate engineers have been inadequately educated to assume engineering leadership roles and U.S. innovative capacity for competitiveness has declined.

More than ever it is critically important for the universities to be responsive to the educational needs of the engineering workforce to enhance competitiveness. America’s global competitiveness depends upon the creativity, inventiveness and leadership capability of its engineers to solve real-world problems responsive to market needs and reform needs to be made at the graduate level to reflect the transformation in the practice of engineering. As Saul Fenster, President of the New Jersey Institute of Technology, notes: “It would seem a tautology that the role of the engineer and the curriculum for the practice of engineering ought to be in harmony.” Today, they are not. He further points out: “There are important forces driving changes in the engineering curriculum … Engineering education must occur in context of international changes, and in consideration of the role of the engineer as a systems integrator, leader, manager, entrepreneur, and innovator… The context for engineering education includes economic and social factors, as well as changes in technology and the magnitude of the complexity and multidimensionality of the problems to be solved. These result in the need to significantly broaden the education of the engineer.”

Today, the status quo of graduate engineering education is being challenged across the nation because U.S. engineering graduate education, with notable exceptions, has kept up with neither the graduate educational needs of engineers in industry nor the substantial changes that have occurred in the practice of engineering relevant to the engineering innovation process itself. The provision for a new balanced emphasis between research-based graduate education and professionally oriented graduate education for engineers has been a long-felt need in industry. Accepting the relationship between first-rate professional engineering education and the practice of engineering at the graduate level has not been easy in today’s research-oriented university environment. But change must occur because it is now evident that “one type” graduate education doesn’t fit all. The major focus of U.S. engineering graduate education continues to be research-based, yet less than 7% of the nation’s graduate engineers are engaged in either basic or directed scientific research. Most of the nation’s graduate engineers, however, are engaged in creative engineering practice and the leadership of technology development in industry for product improvement, process improvement, production, systems development, and operations.

We know today, as we have known for several decades, that industry wants its engineers to grow beyond entry level competence toward higher leadership levels in engineering, and that it is supportive of reshaping a new type of professionally oriented graduate education relevant to the practice of engineering and leadership of technology development. As Gary, former vice president of corporate engineering and manufacturing at General Electric, pointed out: “Great engineering is measured by the proper gauging of people’s needs and the delivery of affordable, high-grade products and services. What industry needs are engineers equipped to score straight A’s on this global final exam … The recent growth of campus engineering research indicates the emphasis universities give to this work, which admittedly is an important part of the drive to rebuild our industrial preeminence. Yet only 5 percent of the engineers in
the U.S. report their primary task as being research, and only about 1 percent indicates that they do basic research. Development is the primary task of engineers.”

D. Fueling U.S. Innovation by Developing Engineers in Industry

Although the Grinter Report was correct to place an increased emphasis on the scientific aspects of an engineer’s education, it failed to recognize the duality of missions that are necessary for graduate education in engineering and the need to emphasize an appropriate balance between graduate education for academic scientific research and graduate education for advanced engineering practice. The Grinter Report, published in 1955, followed the Vannevar Bush Report within ten years. It was strongly influenced by that report which suggested that engineering innovation stems primarily from basic academic scientific research performed at the nation’s research universities. The Grinter Report set the direction for research-based graduate education in the U.S. system of engineering graduate education for the past four decades. But the practice of engineering for systematic technological innovation has changed substantially and American engineering graduate education must respond to this new reality.

Today, we need a new balance in graduate education to meet the nation’s needs not only for excellence in research-based graduate education but also for excellence in professionally oriented engineering graduate education for the practice of engineering and leadership of technology development in industry. To make this change, the colleges of engineering and technology must renew the covenant between professional education and innovative practice. Universities serve multiple missions, directions and constituencies, one of which is basic research, another is the human-resource development of leaders for the creative professions such as engineering. Today, universities must broaden their scope and distinguish themselves by fulfilling their broader missions. Colleges of engineering and technology must become long-term developers of the nation’s engineering leaders by providing relevant lifelong learning opportunities. As Huband has pointed out: “Society needs engineers who can not only solve engineering problems, but who can participate in bringing ideas and products to market. Educating students to become well-rounded engineers having broad knowledge will require changes in today’s engineering curricula. But these changes have the potential to produce engineers capable of corporate and national leadership.”

As the National Research Council has noted: “The traditional importance of engineering in maintaining American strategic and defensive strength has come to be matched by its crucial role in maintaining U.S. economic competitiveness in the international marketplace. Both responsibilities depend on the problem-solving approach that is at the heart of engineering.” America’s technological thrust in peace or war depends largely upon the creative, innovative and leadership capacity of the nation’s graduate engineering workforce in industry that in turn depends upon the adequacy of the nation’s support structure for professional engineering education. However, American engineering graduate education continues to provide an over-reliance on the linear, sequential model for research-driven engineering innovation and on a model of research-based graduate education that is neither sufficient nor adequate to professionally educate the nation’s graduate engineering workforce for innovative engineering and leadership of technology development for long-term prosperity. Other models are needed. As the 1994 ASEE-Green Report indicated, there are several key issues that will help to shape needed reform in U.S. engineering education. Many universities and their engineering colleges have aspired to the model of excellence of the research-intensive university. But, the nation is now demanding new models that serve broader needs for excellence in engineering practice for continuous incremental improvements, breakthrough innovations, and leadership of technology development. Charles Vest, President of MIT and co-chairman of the ASEE-Green Report, notes that for too long we have all been striving for a single model: the comprehensive, Ph.D. granting research university. He feels that we need different styles of education to meet the needs of different students, and that engineering education must return closer to the roots of engineering practice.
III. MEETING THE CHALLENGE FOR CHANGE: CREATING A NATIONAL COLLABORATIVE WITH INDUSTRY

As the Council on Competitiveness has pointed out: “American universities have an indispensable role to play in developing the nation’s human capital in science and technology … The most vital mission of U.S. universities is education: it is a mission that no other institution can perform … To ensure that the United States has the human resources required for a healthy R&D system, universities should restructure graduate study to open a broader spectrum of career opportunities to Ph.D. students and to develop a credible practice-oriented master’s degree … Creating master’s degree programs geared to the needs of the workplace would be particularly valuable.” 21

A. Time for Action

The time for reform in reshaping graduate education to enhance U.S. innovative capacity is immediate. Broad sweeping changes are required in U.S. engineering graduate education to develop a different type of professionally oriented, innovation-based graduate education, as a complement to research-based graduate education, that better develops America’s engineering workforce for leadership of continuous technological innovation for competitive advantage. While America’s system of graduate engineering education has placed primary emphasis on providing research-based graduate studies for the 7% of the nation’s graduate engineers (and faculty) who pursue basic research and academic scientific research careers it is now timely to place equal emphasis on the systemic development of a complementary type of professionally oriented graduate education for the 93% of the nation’s graduate engineers who are pursuing high caliber professional careers. New models for professionally oriented graduate education must be created and implemented that better support the lifelong professional development needs of the graduate engineering workforce. These models must complement research-based graduate education for academic scientific research and must be more relevant to the real-world needs of the practice of engineering for innovation and leadership. The impact of this reform will be substantial. As Whitfield has pointed out: “It is taken as self-evident that the creative output of engineering will be raised quickest and over the widest area by successful efforts to improve the creativity of the engineer already in industry, specifically the engineer who has added an adequacy of experience to his basic technical training.” 22

B. Creating a National Collaborative: In Reshaping Graduate Education for Competitiveness

Today, engineering education must be thought of in a new context because the driving forces for reform are significantly broader and deeper in scope than previously recognized by the academic research community: they deal with professional education issues at the very core of the foundations of engineering practice for the 21st century. Bennett is correct in noting that change is risky but that failure to change can be more risky. 23 Other nations are responding to improve their national innovation systems in engineering at the graduate level. It is too risky for the U.S. to be complacent and not respond to the long felt need for corrective improvement in graduate education relevant to the practice of engineering and the leadership of technology development to enhance U.S. competitiveness. However, our major problems and resistances to educational change lie within the universities themselves. While several notable educational innovations have been made, most have been piecemeal at best, seeming never to break into the mainstream of U.S. graduate engineering education at the national level. This is no longer acceptable if America is to sustain a competitive advantage in advanced engineering and technological leadership in the global economy. This situation will continue unless there is deliberate, planned systematic action for educational leadership at the national level. In order to meet the challenge for sustainable change, the ASEE-GS Division has formed a National Collaborative Task Force to spearhead action across the country to purposefully address the compelling issues for needed reform in engineering graduate education. The National Collaborative is charged not only to identify the issues for change (with the involvement of participating industry) but also to conceptualize and implement new models for educational change within participating universities across the nation as a system of pilot demonstration.
projects for innovative graduate engineering and technology education to improve U.S. innovative capacity for competitiveness. A summary of the mission, strategy and action items is provided below:

➢ Mission of the National Collaborative

To more broadly shape professionally oriented engineering graduate education in cooperation with industry relevant to the practice of engineering and leadership of technology development for the advancement of engineering, encouragement of innovation and inventiveness, promotion of responsible technology development and engineering leadership, and

To implement this unique innovation in curricular design and teaching methods as a national demonstration project in order to advance engineering practice and leadership of technology development in industry and for transfer and sharing of best educational practice across the nation.

➢ Strategy for Educational Change

The National Collaborative will work as a task force in close partnership with leading industry and key government agencies that have the responsibility to promote the advancement of U.S. technology for economic competitiveness, long-term prosperity and our national security. These sectors make up the broad stakeholder base that professional engineering education serves. Collaboration with these groups will ensure the vitality and relevance of the pilot project as well as the sharing of new concepts to meet the needs of the practicing profession in industry. To meet this challenge we will use the following integrative strategy:

- Use a systems approach in reshaping graduate engineering and technology education relevant to the practice of engineering and leadership of technology development for innovation.
- Create a guiding coalition of regional universities, national research universities and partnering industry across the nation.
- Build a sustainable national collaborative for educational innovation.
- Build upon existing strengths and proven concepts pioneered by participating universities in collaboration with industry.
- Engage practicing engineering professionals across the U.S. in continuous innovation in graduate education.

➢ The Action Plan

The overall objective is to make a deliberate transformation in U.S. graduate engineering education relevant to the practice of engineering and leadership of technological innovation that better meets the needs of the practicing profession in industry to improve U.S. innovative capacity and competitiveness. Although numerous calls for change in engineering graduate education have been made, few changes have been implemented. To reverse this trend, the National Collaborative will implement planned educational innovation at the national and regional levels that stimulates technological innovation for regional economic growth across the country as regional clusters for innovation that are the foundations of U.S. competitiveness. To initiate this paradigm shift in graduate profession education, the National Collaborative believes that action must be taken on several fronts. The National Collaborative will address eight key action items that it believes are necessary to move this reform forward.
Eight Key Action Items

1. Assessing the Continuous Growth Needs of Engineers in Industry
The National Collaborative believes that the first task in reshaping the graduate education of engineers should be to assess the graduate needs of engineers in regional industry across the U.S. and to reaffirm the objectives that differentiate high-quality professionally oriented graduate education relevant to the practice of engineering and leadership of technology development from those of scientifically oriented graduate education for academic research.

2. Fostering Lifelong Learning of Engineers as Creative Professionals and Leaders of Technology
The second task should be to develop new types of high-quality, professionally oriented engineering graduate education that purposefully foster lifelong learning of engineers as creative professionals through the several stages of growth in engineering practice, that better support the practice of engineering, and that further develop the engineer’s technical, creative, innovative and leadership potential for responsible practice.

3. Reshaping Graduate Curricula to Foster Engineering Innovation and Leadership
The third task should be to create new types of needs-driven, professionally oriented graduate curricula that are specifically designed relevant to the engineering method for systematic innovation, the progressive dimensions of engineering practice for leadership of technology development, and the increasing responsibilities that engineers encounter throughout their professional careers.

4. Creating Integrated Curricula that Link Graduate Studies with Technology Development
The fourth task should be to create new curricular models that integrate the professional’s further graduate studies with on-going creative engineering work, experiential-based learning, self-directed learning and actual leadership of technology development-innovation in industry.

5. Fostering Multidisciplinary Learning Organizations where Innovation Flourishes
The fifth task should be to create new innovative learning organizations for high-quality professional engineering education that are more in tune with the way experienced engineers in industry learn, grow and develop as creative professionals at the cutting edge of technological innovation and engineering leadership for world-class competitiveness.

6. Building New Types of Engaged Professional Graduate Faculty in Engineering
The sixth task should be to build and continuously develop new types of high caliber, professionally oriented faculty by drawing from the multidisciplinary resources of core faculty from the engineering schools and adjunct faculty from other universities and from regional industry who are at the cutting edge of technological advancements, technology policy making and engineering leadership.
7. **Fostering University-Industry Engagement Through Clusters of Innovation Across the U.S.**

The seventh task should be to create new models for university-industry engagement that better link professionally oriented engineering graduate education and faculty interaction with regional clusters for innovation across the U.S.

8. **Building a Critical Mass for Creative Collaboration and Transfer Across the U.S.**

The eighth task should be to create a critical mass of innovative pilot programs as a national demonstration project for creative collaboration and transfer across the U.S.

➢ **Deliverables**

As with management of any large-scale systems engineering project, the vision must be far-reaching but there must be predetermined deliverables and checkpoints to keep the project on course. There are seven deliverable that will result from this national project. These are:

- Regional needs assessment studies to determine the continuous graduate needs of engineers and technology leaders in innovation clusters across the U.S.
- Identification and definition of the stages of professional growth in engineering beyond entry level, the critical skills and progressive dimensions of creative engineering practice, and the increasing responsibilities that engineers encounter throughout their professional careers for leadership of technology development and innovation in industry.
- Curricular design of new graduate programs that support the progressive dimensions, stages of growth and responsibilities of engineering that are integrative with on-going practice for technology leadership and innovation in industry.
- Institutional acceptance and support; and the development of sustainable funding for implementation and continuous improvement.
- Development of new course modules, seminars, and distinguished lecture series in engineering; and development of new mechanisms for collaborative educational R&D for improvement.
- Recruitment of practicing student body within regional industrial clusters for innovation across the U.S. and development of new mechanisms for faculty recruitment and professional development with industry.
- Development of new engagement mechanisms for university-industry-government partnership that integrate graduate professional education and directed scientific research to the needs of the practicing profession in regional industry.

IV. **SETTING THE AGENDA: NEXT STEPS FOR ACTION**

The National Collaborative believes that this is a bold initiative between engineering graduate education, government (local, state, and federal), and industry that will strengthen U.S. innovative capacity and spur new technological innovation and regional economic growth across the country. The national impact and educational merit of this initiative is far-reaching in fostering the development of clusters of innovation across the country by aligning innovative graduate education for engineers in industry with on-going regional technology development and innovation.
A. Implications

The impact of this initiative to the U.S. economy is significant. As Michael Porter, Professor in the Harvard Business School and Co-Chair of the Innovation Initiative of the Council on Competitiveness notes, clusters of innovation play a major role for regional economic growth across the country by serving as regional foundations of U.S. competitiveness.24 As Rosabeth Kanter points out: “Innovation refers to the process of bringing any new, problem-solving idea into use ... Innovation is the generation, acceptance, and implementation of new ideas, processes, products or services.” 25 Improving university-industry engagement mechanism in research and in realigning graduate curricula to better meet the needs of the engineering workforce for innovation is an important part of fostering cluster development and sustainability. While the U.S. has been slow to respond to its human-resource development needs in technology, other nations have been investing in their engineers during the past two decades and are getting a 20 to 1 return on their human-resource investments.26 The issues for change in engineering graduate education are known and the issues of what must be done to renew U.S. innovative capacity in the nation’s industrial infrastructure are now clear. We must instill in management a reverence for innovation in industry; we must rebuild technology development as a core competency in industry; and we must reinvent graduate engineering education to be more responsive to the needs of industry.

Today, the U.S. engineering workforce must play a heightened role in the creation, development, and leadership of new innovative technology for competitiveness. We know that ensuring the supply of engineers for industry, and ensuring their further graduate development for technology leadership roles, are key ingredients in building sustainable clusters for industrial innovation and in building inhouse capability for technology development. The relationships between fundamental research (performed at universities) and creative engineering innovation (performed in industry) have changed substantially in the national innovation system. This new role depends upon the responsiveness and capability of American graduate engineering education to strengthen the innovative capacity of the engineering workforce in industry as it has done in the past to strengthen the research capacity of the academic workforce at the universities. Today the acceleration of technology generation and the development of new innovations that promise significant commercial and national security payoffs depends upon the human-resource development of the domestic engineering workforce in industry, which now must be placed at the top of the national agenda. The financial returns that can be generated by universities through increased graduate enrollments of domestic students, increased national prominence, increased endowments, and improved university-industry engagement are significant. By building first-rate institutions for professionally oriented engineering graduate education, the economic returns to state governments and the nation in enhancing innovative capacity for regional economic growth across the country are also substantial.

B. Leading the Change

As with any large-scale systems innovation, the task is not easy. Because of tight budgetary constraints and the existing faculty reward structure at many institutions, it is unrealistic to think that systemic reform will be made to strengthen the nation’s innovative capacity by reshaping the graduate education of engineers in industry unless there are outside forces driving the reform and that will bring increased financial return and other benefits to the universities. Many universities are still prioritizing their missions for excellence, singularly, as those programs that primarily contribute to the internal research base of their institutions in order to attract external federal research grants and overhead. Because of the existing research emphasis, most universities will probably not give high priority in allocating scarce financial resources to improving professionally oriented graduate education for the practicing profession. Other universities, who are redefining their missions more broadly, must provide educational leadership for change.27 The long-term benefits resulting from this change will not detract from basic research efforts, but will complement them. However, the needed changes will not occur by themselves. It is time for purposeful action.
C. Building Creative Collaboration with Industry

As Gerald Jakubowski, President of ASEE and Dean of Loyola Marymount University, has suggested, ASEE needs to take action in the following areas: change the perception that ASEE is only involved in promoting and improving undergraduate engineering education by expanding ASEE activities related to research and graduate engineering education; reverse the decline in the number of Americans receiving graduate degrees in engineering by promoting the importance of graduate level engineering education, and; increase the involvement of industry in engineering and technology education, specifically to ensure that the education provided to students is relevant, by listening to the needs of industry. To meet this challenge, the National Collaborative will provide an alliance of innovative universities, industry and government agencies working together with mutual commitment. This is an investment in America’s future. The stakes are high but the cost is affordable. The physical resources, intellectual resources and leadership resources needed for this change are in place in academia and in industry. Most of the proposed educational innovations have already been made, have been tested, and are achievable. But they have not been integrated as a coherent system. However, the universities cannot be expected to reshape graduate engineering education alone with their limited funds and tight budgets. What is required is start-up funding and sustained financial support from industry, government, and foundations to make this initiative a reality. As a task force, and catalyzing agent for change, the National Collaborative has the expertise, organizational resources and commitment necessary to implement this bold initiative as a pilot demonstration project across the country with industry’s support. It will work with leaders in industry, the societies and academies, and government agencies that are responsible to maintain the strength of the nation’s engineering workforce for competitiveness and for national defense. This is a solid investment in our future innovative competitiveness in engineering and the impact to the U.S. economy is nationwide.

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