AC 2009-446: STRENGTHENING THE U.S. ENGINEERING WORKFORCE FOR TECHNOLOGY INNOVATION: WHY THE PROFESSIONAL GRADUATE DEGREE IN ENGINEERING

Roger Olson, Rolls-Royce Corporation

Donald Keating, University of South Carolina

Thomas Stanford, University of South Carolina

Strengthening the U.S. Engineering Workforce for Innovation: Why the Professional Graduate Degree in Engineering?

1. Introduction

This is the third of four invited papers prepared for the National Collaborative panel session concerning the deliberate advancement of professional engineering graduate education relevant to the needs of creative engineering practice in industry to enhance U.S. technological innovation and competitiveness. The paper sets a solid foundation and educational philosophy of professional engineering graduate education specifically designed to encourage, inspire, and enable the continued professional growth of the nation's engineers, working in industry, beyond the baccalaureate entry-level [level 1 and 2]. It differentiates between the traditional aims of graduate education for scientific research for academic/research positions and those of advanced professional engineering graduate education for engineering leadership positions in industry for effective technology development innovation, and other creative engineering works.

The comparison differentiates between the traditional Master of Science and PhD degrees for scientific research, and the professional Master and Doctor of Engineering degrees for growth in professional, creative, and innovative engineering practice. This comparison extends through the professional Master of Engineering [M.Eng. level 3], and the professional Doctor of Engineering [D.Eng. level 4-6]. Professional Fellow levels [level 7-9] of responsible engineering responsibility and leadership are generally conferred by an engineer's employer.

The paper also builds on the positive outcomes already established as best practice in other nations, such as the UK for professional M.Eng. and D.Eng. programs. While taking best practice and lessons learned from the UK model, the National Collaborative is building a model specific to the needs of U.S. engineers in industry to properly enable their skills, and to promote lifelong learning, development and growth throughout a graduate engineer's professional career. Creative engineers enhance their skills beyond their highest attained degree, although coherent advanced degree programs are beneficial to properly hone these skills, and to enable practitioners to achieve their fullest creative potential for effective leadership of engineering innovation.

2. What is a Professional Graduate Degree in Engineering?

A professional graduate degree in engineering for the practicing engineer in industry is designed to help the engineer advance in the field of applied engineering, whereas today's engineering graduate degree more frequently prepares students for advanced careers in the academic/research arena. A professional graduate degree in engineering will provide an engineer in industry a path towards either engineering management; or a deeper knowledge in a chosen specialty such as aerodynamics, structural mechanics, or computational fluid mechanics.

3. Why is a Professional Graduate Degree in Engineering needed?

A practicing engineer in industry requires a means to advance beyond the Baccalaureate degree entry-level in engineering practice, besides work experience, mentoring by more senior engineers, and in-house training. In today's innovation-driven economy, the vast majority of engineering innovations are needs-driven and market-focused, requiring deliberate engineering problem solving ability and responsible leadership. Engineering for creative technology development and innovation is a purposeful and systematic practice. It is not a linear or sequential process that follows basic research as portrayed by Vannevar Bush in 1945. [1] Creative engineering projects in industry frequently drive the need for directed strategic research efforts at universities, when necessary, or when anticipated, to gain a better understanding of the natural phenomena involved.

The need to prepare future leaders within the engineering profession has truly changed. Teaching them improved skill sets is becoming increasingly more important. The ability to select team members, facilitate open discussions, and to resolve conflicts is now as important as the technical knowledge of engineering. Properly preparing our future leaders and technical experts is required to achieve industrial success. This preparation of our future leaders and technical experts cannot be left to chance; it must be emphasized throughout an engineer's graduate education.

3.1 The Need for Experience

- Although engineer's, upon graduation with a Baccalaureate degree know the basic principles of their field, they, most likely, have not learned how to properly apply their knowledge, and generally learn this from on-the-job experience and training, as well as from mentoring by more experienced engineers.
- Engineers must receive effective feedback along the way to know how they are progressing to realize their true strengths, and to recognize areas where further development is needed. Annual performance ratings for each engineer must be conducted in a constructive manner, and reviewed one-on-one between the manager and the engineer.
- The field of engineering is changing so rapidly, that an engineer must keep up with advances in their field to avoid obsolescence. Engineers are also driving the changes in their fields.
- Most graduate study programs are aimed at engineers who intend to pursue research, and are traveling down the academic route
- There is a need for professional engineering graduate study programs focused on developing engineers who want to remain in industry.

3.2 The Need for Professional Engineering Graduate Studies

To meet this challenge, the National Collaborative Task Force is engaged in a complex project that requires a total systems approach. The stakes to enhance the innovative capacity of the U.S. engineering workforce for competitiveness are high.

- Advanced degrees for professional engineers:
    - A Professional Masters degree, with a company oriented directed project rather than a research thesis
    - A Professional Doctorate of Engineering degree, with a company oriented directed project rather than a research thesis
    - Industry experienced faculty are needed to teach the professional engineers. Some of these could/should be visiting/adjunct faculty who are experienced practicing engineers.

3.3 Transforming Engineers into Leaders

- In many engineering organizations today, there are multiple tracks for advancement. To be successful in any of these tracks, professional graduate engineering education is needed.
    - One track is to progress toward increased specialization and increased value to the company. These engineers need a professional graduate education in their field of specialization.
    - Another track is to become a Project Manager.
    - The third track is to progress into a management role, and become a leader.
        - For an engineer to succeed in the management track, leaders must groom the engineer for a leadership role. One way to do this is to provide a professional graduate engineering education which includes both engineering and management classes.

4. Professional Engineering Graduate Education

Professional engineering graduate education will play a vital role in the transformation of engineers into innovators and leaders. [2,3,4,5] To meet this challenge, the National Collaborative Task Force is evolving a series of preliminary guidelines for engineering graduate education reform to develop a professionally oriented graduate education to enhance the innovative capacity of the U.S. Engineering Workforce in industry (see Appendix B). Engineering leaders must be developed that will guide engineers to develop innovative new designs, leading to products that will provide what the customer wants and needs. Management styles that will both encourage innovation, and meet the basic human needs of engineers are needed, including the adoption of cutting-edge concepts and best practices from other nations, thus laying the groundwork for turning theory into practice.

4.1 The Evolving of Preliminary Guidelines for Professional Engineering Graduate Education by the National Collaborative Task Force

A new type of professionally oriented engineering graduate education that develops the innovative capacity of the U.S. engineering workforce for competitiveness is required. It must also support the innovation skills required of engineers at all levels of leadership responsibility in industry. The National Collaborative Task Force is leading the development of a new model for

the professional education of graduate engineers in industry focusing on innovation, leadership, and solving unknown problems. Educating engineers as creative professionals is a career-long process of growth and professional development, including the development of intrinsic creative and innovative potential for leadership in engineering practice. This process extends beyond entry-level undergraduate education to the highest levels of responsible engineering leadership within the practicing profession of engineering. Professional education at all levels requires an integrative combination of self-directed learning, experiential learning, innovation-based learning, and advanced studies combined with real-world experience in creative engineering practice. The professional graduate engineering programs developed through the National Collaborative Task Force should be broad enough that students can specialize in a particular field of engineering through the use of electives, while remaining focused on developing engineering leaders.

The National Collaborative Task Force believes that the development of engineers in industry, or government service, as creative professionals, innovators, and leaders can be classified by three stages of growth:

- Early career development — From Level 1 through Level 3
- Mid-career development — From Level 4 through Level 6
- Senior career development — From Level 6 through Level 9

See Appendix A for a more detailed description of the responsibilities and expectations at each engineering level.

5. Conclusions: A Work in Progress —
Why a Professional Postgraduate Education for Engineers in Industry is Needed

The United States needs a workforce that is nurtured at all levels of engineering practice beyond entry level to fuel America's preeminence for world-class technology development and innovation. Professional engineering education cannot end at the entry level, or with a professional master's level education, if we want to unleash America's engineering potential for competitiveness and national security purposes. Close collaboration between industry and universities will be critical to the success of this reform. The National Collaborative Task Force believes that the further graduate development of the U.S. engineering workforce in industry can be done by neither universities, nor industry working alone. Reinventing professional engineering education for creative engineering practice requires industry's steady and consistent input defining what we want the nation's engineers to do and to become. The next steps of the National Collaborative Task Force will be to implement these recommendations into action in the national interest. [6,7]

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Appendix A

Stages of Professional Maturation, Autonomy, and Responsibilities in Engineering Practice for Responsible Technology Leadership

Level/ Stage of Growth	Typical Responsibilities-Autonomy-Judgment
ENGINEER 9	An engineer-leader at this level is in responsible charge of programs so extensive and complex as to require staff and resources of sizable magnitude to meet the overall engineering objectives of the organization.
ENGINEER 8	An engineer-leader at this level demonstrates a high degree of creativity, foresight, and mature judgment in planning, organizing, and guiding extensive engineering programs and activities of outstanding novelty and importance. An engineer-leader is responsible for deciding the kind and extent of engineering and related programs needed for accomplishing the objectives of the organization.
ENGINEER 7	In a leadership capacity, a senior engineer is responsible for an important segment of the engineering program of an organization with extensive and diversified engineering requirements. The overall engineering program contains critical problems, the solutions of which require major technological advances, and opens the way for extensive related development.
ENGINEER 6	In a leadership capacity, an engineer plans, develops, coordinates, and directs a number of large and important projects or a project of major scope and importance. Or, as a senior engineer, conceives, plans, and conducts development in problem areas of considerable scope and complexity. The problems are difficult to define and unprecedented. This involves exploration of subject area, definition of scope, and selection of important problems for development.
ENGINEER 5	This is an engineer in a leadership capacity who plans, develops, coordinates, and directs a large and important project or a number of small projects with many complex features. Or, as an individual principal engineer, carries out complex or novel assignments requiring the development of new or improved techniques and procedures. Work is expected to result in the development of new or refined equipment, materials, processes, or products. Technical judgment, knowledge, and expertise for this level usually result from progressive experience.
ENGINEER 4	An engineer at this level plans, schedules, conducts, or coordinates detailed phases of engineering work in part of a major project or in a total project of moderate scope. This is a fully competent engineer in all conventional aspects of the subject matter of the functional areas of

	assignments. An engineer at this level devises new approaches to problems encountered. An engineer at this level independently performs most assignments requiring technical judgment.
ENGINEER 3	An engineer at this level performs work that involves conventional types of plans, investigations, or equipment with relatively few complex features for which there are precedents. Requires knowledge of principles and techniques commonly employed in the specific narrow areas of assignments.
ENGINEER 1/2 (Entry-Level Engineer) .	An entry level engineer requires knowledge and application of known laws and data. Using prescribed methods, an entry level engineer applies standard practices/techniques under the direction of an experienced Engineer

Appendix B

Guidelines for Engineering Education Reform to Develop Professionally Oriented Graduate Education to Enhance the Innovative Capacity of the U.S. Engineering Workforce in industry

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GUIDELINES FOR NATIONAL COLLABORATIVE TASK FORCE

- Focus on innovation and leadership

- Focus on development of U.S. Engineering Workforce for innovative competitiveness in industry, second to none in the world

- Vision ─

  "Innovation fosters the new ideas, technologies, and processes that lead to better jobs, higher wages and a higher standard of living. For advanced industrial nations no longer able to compete on cost, the capacity to innovate is the most critical element in sustaining competitiveness."

  Council on Competitiveness

- Workforce Development ─

  "The Council's business leaders agree that every company's most important asset is the people who walk in its doors every morning. Talented people creating new ideas and innovative technologies keep the economy strong, and growing stronger. The education and training that spark Americans' creativity and give them cutting-edge skills are a key to competitiveness.

  Council on Competitiveness

- Create a new, innovative professional curriculum combined with engineering practice that matches and supports the progressive core-competence skills required for effective engineering leadership of technology development & innovation in industry ─ from beginning Entry Level Engineer through the Chief Engineer / Vice President of Engineering & Technology level for corporate technology responsibility

- Graduate centers that will be "statewide clusters" for advanced professional education for engineering innovation and leadership in all 50 states across the nation

- Use the combined formidable teaching and human resource strengths of regional universities and industry in this process

- Form a unique collaborative partnership between industry and universities in developing the creative and innovative capacity of the U.S. Engineering Workforce in industry for world-preeminence in technology development & innovation

- Enable and encourage "life-long learning" within the engineering population of a company to stimulate innovation