Growing the National Innovation System: Defining the Characteristics of Innovative Professional Graduate Education at the Master, Doctor, and Fellow Level for Technology Leaders in Industry

D. D. Dunlap,[1] S. J. Tricamo,[2] D. H. Sebastian,[2]
D. A. Keating,[3] T. G. Stanford[3]

Western Carolina University [1] / New Jersey Institute of Technology [2]
University of South Carolina [3]

Abstract

This is the third paper in the special panel session on reshaping professionally oriented graduate education to be more relevant to the needs of the practicing profession in industry to ensure a strong U.S. engineering workforce. This paper suggests a framework of guidelines for curricular design of innovative master, doctoral, and fellow level professional graduate programs crafted to meet the career-long needs of engineering professionals in industry and guided by the incorporation of five major attributes of high-quality graduate programs that positively affect the growth and development of working professionals. The guidelines are based on the functional requirements, tasks, and responsibilities that engineering leaders encounter throughout their professional careers. The paper presents a new vision for shaping integrated (holistic) professional graduate education for working professionals as a "system for lifelong learning" that enables their continuous professional development thereby continuously strengthening U.S. innovative capacity for competitiveness. Attention is drawn to the need to integrate graduate studies with experiential learning and the advanced practice of engineering for systematic development, innovation, and leadership of technology in industry.

1. Introduction

Whereas professional master and doctoral programs were originally established in engineering as an alternative to research-based graduate education for young resident students to pursue professionally oriented studies prior to practice. Today, most engineering professionals enter the U.S. engineering workforce immediately upon completion of their undergraduate studies. Consequently, a new opportunity for professional graduate education needs to be developed that better supports the lifelong learning needs of these graduates as high-caliber practitioners and leaders of technology throughout their active careers. Mastery of all of the skill sets that technology leaders need to acquire for successful professional careers cannot be achieved solely in the undergraduate years of a professional's education. Experience, further learning, and actual creative practice in technology development is required.

2. Defining the Aims and Orientation of Postgraduate Professional Education for Engineering Practice, Innovation, and Technology Leadership

Experiential learning plus further graduate studies, which are relevant to the professional's needs, plays an important role in the further professional education of engineers. Faced with the long-term career needs of increasing responsibility, (which have been identified in the second paper of this panel session), engineers require a "system" of postgraduate professional education that supports lifelong growth beyond entry-level which is concurrent with their professional practice while they are fully employed.[1]

2.1 Aims of Postgraduate Professional Education

Alternative paradigms for professional graduate education, which augment research-based graduate education, are now feasible. Based upon recent advancements that have already occurred in professionally oriented graduate education across the nation and a heightened sense of urgency in ensuring a strong U.S. engineering workforce for competitiveness, the timing for executing innovative change and designing postgraduate professional education as a "system for lifelong learning" which is more relevant to the career-long needs of the nation's engineering leaders has never been more appropriate. The transformation that the National Collaborative Task Force proposes neither detracts from nor competes with traditional research-based graduate education or the university's research function. Rather, it enhances the university's mission of professional education by developing high-caliber professionals for technology leadership roles in industry and government service.

As America competes in the global economy, one type of graduate education doesn't serve everyone or meet all needs for technology and science. Because the process of engineering for creating technology and the process of research for scientific discovery are quite different, different types of graduate education are required that are specific to the needs of both functions. Educating engineers as creative professionals does not end at the baccalaureate level. To be more precise, undergraduate education is the beginning of a career-long journey. Undergraduate education serves as the foundation for entry into engineering practice and technology at the basic level. The primary purpose of postgraduate professional education is to provide an integrated opportunity at the advanced level which is concurrent with practice and enables experienced practicing professionals to continue to grow professionally beyond entry level. For practicing engineers who are or who want to be technology leaders, it is imperative to obtain their fullest creative and innovative potentials because of the responsible charge of significant technology endeavors.

2.2 Orientation of Postgraduate Professional Education

Educating engineering leaders as professionals requires a holistic combination of further experiential learning, further graduate studies, and actual creative practice in engineering beyond the baccalaureate level. Whereas traditional graduate programs are research-oriented and focus primarily on inquiry-based learning to prepare young resident students for careers centered on academic research and teaching, the focus of postgraduate programs for experienced engineers must be quite different. However, the rigor is not lessened. At the advanced level, postgraduate programs for practicing engineers need to be technology-oriented and focus on innovation-based learning to further the growth and development of working professionals who are already in industry. Graduate curriculum for practicing engineers who have an already established technology competency base, and whose careers are centered on the practice of engineering for the conceptual design, development, innovation, and need appropriate graduate education leadership of new and future technologies such that they are quick to respond to real-world needs. At this level, a professional's postgraduate education must be built upon an integrated approach that includes not only a curriculum of learning of further advanced studies, but also a curriculum of learning that combines self-directed learning, experiential-based learning gained through progressive experiences in engineering practice, and innovation-based learning gained through actual engagement in the leadership of continuous creative technology development including technological innovation responsive to society.

3. Building the Transformation on Attributes of High-Quality Graduate Programs that Positively Affect the Further Growth and Development of Working Professionals for Technology Leadership

The National Collaborative Task Force recommends a transformation that is bold, visionary, and attainable. The transformation will promote the advancement of graduate education in engineering and technology to a new level that will stimulate technological innovation and economic development across the United States. The resources needed in implementing this transformation across the country are at hand. But the change requires a new way of thinking. No longer can we afford to view engineering education as a one-time process consisting of the sum total of knowledge and skill-sets to be attained prior to practice, completed within four years at the undergraduate level, or to be considered terminal at the master's level if we are to unlock the creative, inventive, innovative, and leadership potential of the U.S. engineering workforce for competitiveness in the new economy.

3.1 Defining Program Quality for Working Professionals

Much of the supporting educational research required for this transformation has already been performed. As a nation we have already built a "silent success" in developing high-quality outreach programs at the graduate level [Conrad, Haworth, Millar, 1993, 1997].[2,3] Based on the national study for the Council of Graduate Schools, Conrad and Haworth have identified five clusters of attributes as the critical factors of high-quality programs that strengthen graduate experiences and have positive long-term effects on the participant's growth. These attributes can now be extended through professional master, professional doctoral, and fellow level graduate programs for working professionals in engineering and technology. Appendix A in this paper reflects the attributes for high-quality professionally oriented graduate programs. These attributes include:

- Engaged Participants
- Participatory Cultures
- Interactive Teaching and Learning
- Connected Program Requirements
- Adequate Resources

While the conventional measurements of program quality for traditional research-oriented graduate programs in engineering and science have been centered primarily on the quantity of expenditure of external research funding and productivity of the research faculty, Conrad and Haworth have proposed a new engagement perspective and definition of high-quality programs — "as those which contribute to enriching learning experiences for students that have positive effects on their growth and development." Hence, the perspective of program quality that supports a new vision of postgraduate professional education as a "system" of lifelong learning for working professionals is quite different from the conventional perspective of program quality for research-based graduate programs. As Conrad and Haworth point out:

> "By defining high-quality programs as those that contribute to enriching learning experiences for students in ways that positively affect their growth and development, the theory focuses on a simple but compelling definition: one that emphasizes student learning and development as the primary purpose of the higher learning … the theory builds upon an increasingly shared view that the development of student talents and abilities is at the core of higher education."
>
> "Our theory of program quality is organized around one central idea: student, faculty, and administrative engagement in teaching and learning. That is, high-quality programs are those in which students, faculty, and administrators invest significant time and effort in mutually supportive teaching and learning. Moreover, high-quality programs invite the participation of alumni and employers of program graduates. In short, our engagement theory emphasizes the dual roles that invested participants play in constructing and sustaining programs of high quality. The theory maintains that in high-quality programs, principal stakeholders — faculty, students, and

administrators — invest in five separate clusters of program attributes, each of which contributes to enriching learning experiences for students that positively affect students' growth and development."

Although concise in statement, the concept of engagement has profound impact on new ways of thinking about professional engineering education itself. Implementing this needed transformation for provision of lifelong learning for the nation's professional knowledge workers in engineering must continuously develop and sustain the nation's capacity for engineering innovation. From this perspective, the orientation of postgraduate professional education must shift from one of faculty-centered instruction to that of learner-centered professional education and practice in order to foster the further growth and development of the nation's professional knowledge workers in engineering and technology. Hence, these programs require participatory cultures for collaborative learning among the faculty and participant students who are full-fledged practicing professionals in every sense of the term.

3.2 Developing Guiding Principles for Postgraduate Education of Professionals In the Context of Creative Engineering Practice for Innovation and Technology Leadership

The capacity for executing educational theory into purposeful action for sustainable reform in engineering graduate education now exists. Based upon the findings of the national study for the Council of Graduate Schools and the mapping of progressive skill-sets required beyond entry level by the National Collaborative Task Force, we now have the conceptual basis for designing and implementing a new paradigm for high-quality postgraduate education as a "system for lifelong learning" that enables working professionals to continue to learn, grow, and develop throughout their professional careers in engineering and technology endeavors.

Although the overall scope of the national reform calls for new institutional programs, that are specifically designed to meet the needs of industry within local and regional constituencies, the National Collaborative believes that these graduate programs share a common focus and framework that enables the growth of the participant as an individual. The five clusters of attributes, identified by the national study for the Council of Graduate Schools, help in developing a shared framework of guiding principles enabling growth of professional practitioners within technology-based industry across the U.S. The National Collaborative Task Force believes that the framework for the new paradigm shift requires a new mind set and a change of culture that is quite different from the conventional perspective of graduate education for academic research. This new culture should incorporate characteristics required in developing and sustaining high-quality postgraduate programs for creative technology development, innovation, and responsible technology leadership in the context of advanced engineering practice.

4. Designing a New Paradigm for Postgraduate Education that Fosters Lifelong Learning as a System through the Professional Master's, Doctoral, and Fellow Levels of Technology Leadership

The new approach, which we propose, combines relevant professionally oriented graduate curricula with on-going engineering practice and technology development in industry and government service. Appendix C reflects this approach as a matrix of lifelong learning that specifically supports the attainment of skill-sets, knowledge, and experience required for increasing responsibility of technology leadership for systematic technology development. We propose a new vision for professional education along with a very feasible approach that meets the needs of the practicing profession within industry and that supports engineering practice and technology leadership as a "system" from entry-level through the highest levels or engineering leadership. The National Task Force believes that these programs should enable professional growth through all levels of engineering responsibility for project leadership, program leadership, and technology policy making. Appendixes D, E, and F reflect the framework for innovative curricular design as an integrated system of lifelong learning which supports a coherent sequence of graduate studies through the professional master's, professional doctoral, and fellow levels of engineering proficiency respectively.

5. Conclusion

This paper has established the conceptual framework for innovative curricular design in reshaping professionally-oriented graduate education as an integrated "system for lifelong learning" to ensure a strong U.S. engineering workforce for competitiveness. By correlating a coherent framework of professionally-oriented graduate studies and experiential learning activities with the professional qualification standards, skill-sets, knowledge, and experience required for the nation's engineers to compete in the global economy, the National Collaborative Task Force has initiated the third milestone for reform. This milestone sets a bold vision for educational innovation that enables the nation's engineers to continue their professional graduate education and development (while fully employed in industry) from entry level through professional master's, doctoral, and fellow levels of engineering. Strategy for leading the change, for overcoming obstacles of resistance, and for implementing this unique educational innovation, as a national demonstration project across the country, is the next milestone for reform.

References

1. Tricamo, S.J., Sebastian, D.H., Snellenberger, J.M., Dunlap, D.D., Keating, D.A., Stanford, T.G., *Growing the National Innovation System: Assessing the Needs and Skill Sets for Innovative Professional Graduate Education Defined by the Tasks and Responsibilities of Engineer-Leaders in Industry,* Proceedings of the Annual Conference, American Society for Engineering Education, 2003.
2. Conrad, C.F., Haworth, J.G., Millar, S.B., *A Silent Success: Master's Education in the United States,* The National Study by the Council of Graduate Schools, The Johns Hopkins University Press, 1993.
3. Haworth, J.G., Conrad, C.F., *Emblems of Quality in Higher Education: Developing and Sustaining High-Quality Programs,* Allyn and Bacon, 1997.
4. Dunlap, D.D., Willis, R.E., Keating, D.A., Stanford, T.G., Bennett, R.J., Mendelson, M.I., Aherne, M.J., *Understanding and Utilizing Adjunct Professors for Non-Traditional Engineering and Technology Graduate Education,* Proceedings of the Annual Conference, American Society for Engineering Education, 2002.
5. Bush, V., *Science: The Endless Frontier,* Office of Scientific Research and Development, 1945 (reprinted 1990, National Science Foundation).
6. National Society of Professional Engineers, *General Characteristics, Typical Duties, and Responsibilities of Engineers for Levels I-IX*, 2002.

Biography – National Collaborative Task Force – Panel on Professional Graduate Curricula

DUANE D. DUNLAP is professor and department head of engineering technology, Western Carolina University.

STEPHEN J. TRICAMO is professor of industrial and manufacturing engineering, and former dean of engineering, New Jersey Institute of Technology.

DONALD H. SEBASTIAN is professor of industrial and manufacturing engineering, and vice president for research and development, New Jersey Institute of Technology.

DONALD A. KEATING is associate professor of mechanical engineering, University of South Carolina.

THOMAS G. STANFORD is assistant professor of chemical engineering, University of South Carolina.

Appendix A

Attributes for Developing and Sustaining High-Quality Postgraduate Programs for Working Professionals that are Concurrent with Engineering Practice

---

_

Attributes of High-Quality Postgraduate Professional Programs
For the Practice of Engineering and Leadership of Technology

Based upon the national study for the Council of Graduate Schools (1993), and their comprehensive follow-on work (1997), Conrad, Haworth, and Millar have identified five clusters of attributes for developing and sustaining high-quality postgraduate professional education which contribute to enriching the working professional's learning experiences and that positively affect the professional's growth and development. These findings advance a new perspective on program quality centered on the concept of engagement of working professionals that is quite different from the conventional view of program quality for research-based graduate education that is centered primarily on the academic research productivity and credentials of the faculty. Those attributes that are required in developing and sustaining high-quality postgraduate professional programs center around five primary clusters. They include:

- *Cluster One: Diverse and Engaged Participants*

  Diverse and Engaged Experienced Faculty
  Diverse and Engaged Experienced Students
  Engaged and Experienced Program Leaders

- *Cluster Two: Participatory Learning Cultures*

  Shared Program Direction
  Community of Learners
  Risk-Taking Environment

- *Cluster Three: Interactive Teaching and Learning*

  Critical Dialogue
  Integrative Learning
  Mentoring
  Cooperative Peer Learning
  Out-of-Class Activities

- *Cluster Four: Connected Program Requirements*

  Planned Breadth and Depth Course Work
  Professional Residency
  Tangible Product

- *Cluster Five: Adequate Resources*

  Support for Students

Support for Faculty
Support for Basic Infrastructure

Appendix B

Guiding Principles for Reform

_

The National Collaborative Task Force believes that the framework for reinventing professional graduate education for the nation's engineering workforce should be grounded in a set of eight guiding principles that are fundamental in strengthening U.S. innovative capacity and in sustaining top-quality graduate programs for the practicing profession. These eight principles are:

1. **Align Postgraduate Professional Education with the Critical Skill-Sets and Knowledge Required Beyond Entry Level for Responsible Leadership of Creative Technology Development and Innovation in Engineering Practice**

   - ***Align postgraduate professional education with creative practice.*** Whereas high-quality graduate programs are in place across the nation to sustain U.S. capacity for basic scientific research, high-quality postgraduate programs need to be implemented in engineering that augment the nation's innovative capacity for creative technology development in industry to enhance U.S. competitiveness and to maintain national security.

   - ***A continuum from entry-level to highest levels of leadership.*** Postgraduate programs should be designed to support professional engineering education as a "continuum" that extends beyond entry level in engineering to the highest professional levels for responsible technology leadership in industry and government service. These programs should support the progressive tasks and responsibilities required in creative professional practice for systematic engineering innovation and technology leadership; and they should provide opportunity that promotes the individual growth of engineers for greater professional responsibility in practice commensurate with their fullest creative, innovative, and leadership potentials.

2. **Build World-Class Postgraduate Programs Upon the Attributes that Characterize High-Quality Professional Graduate Programs Across the United States**

   - ***Connected program requirements.*** Postgraduate programs should build upon connect program requirements for integrative learning and practice by combining a coherent curricula of advanced studies and planned learning experiences with the graduate's on-going practice for technology development, innovation, and leadership in industry or government service that includes experiential-based learning, self-directed learning, and engagement in actual top-quality engineering and technology endeavors.

   - ***Actualized "lifelong learning" and individualized education that enables further professional growth.*** High-quality postgraduate programs should create a framework for dynamic curricula development — as a "system for lifelong leaning" and individualization of advanced studies — with broad flexibility and versatility that is tailored to meet the full breadth of professional growth needs and the full depth of technical needs of the graduate so that the participant and the sponsoring industry derive the maximum educational benefit. Each technology leader is unique with unique professional experiences. Hence, it is important to tailor the educational experience so as to meet the professional growth needs of the individual. Accordingly programs should be uniquely crafted to foster individual participant growth: the aim being to provide a high-quality learning experience of maximum benefit to the participant that enables further growth throughout the engineer's professional career. Each program should be dynamic to support curriculum versatility as the participant grows and develops toward his or her unique creative, innovative, and leadership potential in engineering. In other words, whereas conventional graduate education keeps the same courses

- ***Immersion in integrative learning and practice.*** Programs should focus on requirements for immersion in integrative learning and practice at the graduate level. Because the graduate participant is engaged in program activities that are directly relevant to and part of his or her work activities in industry, the program is not viewed as a "part-time" educational experience. Connected requirements for integrative learning and practice should include:

  a) *Planned Breadth and Depth Course Work*

     - Core professional course work
       These professional courses bring to a new level the graduate's understanding of professional topics in engineering relevant to innovative leadership of technology for systematic innovation.

     - Technical electives
       These elective courses help to further strengthen the participant's grasp of specialized topics directly related to his or her industrial activity and are selected to be directly relevant to the graduate's field of technology and expertise.

  b) *Professional Residency*

     - On-going full-time employment in industry or government technology-based creative work
     - Experiential-based learning for immediacy of application in creative work
     - Self-directed learning to gain expertise in the graduate's technological field

  c) *Tangible Product*

     - A substantive directed technology project. The directed technology project is related to the participant's work activities and is chosen to expand his or her professional capabilities and to be directly relevant to the competitive development needs of the graduate's sponsoring industry

     - This project will be at the caliber of professional master, doctoral, or fellow level
       to be directed by the graduate engineer and guided by core faculty and industrial representation

3. Build World-Class Postgraduate Programs by Coupling the Strengths of Experienced Faculty and Industrial Professionals

- ***Engagement of experienced faculty and industrial professionals.*** These programs should build upon the unique strengths of engagement that can be gained by employing world-class experienced adjunct faculty from local, regional, and statewide industry (who are experienced leaders in engineering) with the multidisciplinary strengths of core faculty from the university in combination with formulating an experienced graduate base of practicing professionals in local, regional, and statewide industry who are at the cutting edge of their technological fields.[4]

- ***Formidable strength for U.S. innovative competitiveness.*** The combined innovative strengths that can be synergised by formulating an experienced professionally oriented faculty base of teachers and technology leaders at the graduate level with a graduate student base of experienced graduates across the nation (who are emerging as technology leaders) will be second to none. And it represents America's future to sustain economic competitiveness and national security through technological innovation. Core university faculty and adjunct faculty will be selected who have extensive professional experience at the highest levels of engineering and technology leadership. Experienced graduates from EAC or TAC of ABET approved programs will be admitted who are professionals in every sense of the term; who have an already established competency base in their fields of technology; and who are assuming responsible leadership positions in engineering and technology endeavors for world-class competitiveness.

4. **Build World-Class Postgraduate Programs for Creative Knowledge Professionals Upon a Learner Centered Culture Focusing on Technology Leadership and the Method of Engineering as a Systematic Practice for Innovation**

- ***Create new learning cultures for technology innovation at the postgraduate level.*** Postgraduate programs should focus on creating new types of collaborative learning organizations at the graduate level in which technological innovation and participative learning among professionals flourishes. These programs should focus on creating:

  a) Facilitative learning environments in which graduates learn as active participants rather than as passive learners

  b) Participatory cultures for postgraduate professional education that are learner-centered and which contribute to enriching learning experiences that have positive effects on the further growth and development of experienced professionals in engineering

  c) New educational models for developing professional intellect in the creative professions focused on how creative professionals — as innovators, pacesetters, and technology leaders — learn and acquire expertise through increasing self-directedness wherein the graduate grows not only as a learner of existing knowledge but also as a creative knowledge worker who creates new technological knowledge as a result of his/her creative work in purposeful technology development and innovation

  d) New graduate infrastructures that nurture innovation-based learning which are focused on the method of engineering as a "systematic practice" for purposeful technological innovation and entrepreneurship based on doing-centered learning which develops new innovative technology in industry and technology-leaders simultaneously for continuous improvements and breakthrough innovations

  e) New mentoring cultures wherein core faculty assist the graduate to craft his/her individual program of study and actively guide the thesis/project work along with developing new learning organizations for collaborative creativity that focus not only on individual learning but also on organizational learning wherein interactive teaching and cooperative learning among graduates and faculty flourishes

5. **Create World-Class Postgraduate Education for Working Professionals in Engineering as a System for Lifelong Learning through the M.Eng., D.Eng., and Fellow Levels**

   - ***Align postgraduate education with progressive skill-sets of engineering leadership.*** Postgraduate programs should align curricular design with the mapping of functional requirements, tasks, responsibilities, and attainment of progressive engineering skill sets required for career-long growth in engineering for purposeful creative technology development and innovation.

   - ***A new "system for lifelong learning in engineering.*** These programs should build upon a new framework for coherent curricula design that supports the further growth of professional practitioners in engineering as a "system" for lifelong learning: from entry-level through professional master's, doctoral, and engineering fellow levels of technology leadership.

6. **Build World-Class Postgraduate Programs upon Integrative Learning-Practice that Develops Innovative Technology in Industry and Technology Leaders in Industry Simultaneously**

   - ***Develop innovative technology in industry and technology leaders simultaneously.*** These programs should focus on developing new innovative technology in industry in combination with developing high-caliber engineers as leaders of change concurrently; thereby growing the national innovation system by purposeful action in reinventing graduate education to ensure a strong U.S. engineering workforce and by stimulating new technological innovation across the nation to enhance U.S. competitiveness.

   - ***Project-based learning for innovation and leadership.*** This can be accomplished by developing new paradigms for postgraduate professional education for practicing engineers that focus on project-based learning and by developing new graduate cultures in which professional learning, technology development, and innovation flourishes. What Vannevar Bush did to advance U.S. capability for basic scientific research at the universities and to develop the nation's academic researchers simultaneously,[5] we can now do to advance U.S. capability for technology development as a core competence in American industry and to develop the nation's engineering leaders simultaneously.

7. **Establish Postgraduate Professional Education as a Primary Mission of Universities that Augments the Research Mission**

   - ***Develop financial sustainability of high-quality postgraduate professional education.*** Because financial support for traditional research-based graduate education in engineering and science has been built largely upon the linear research-driven model of innovation and federally-driven research grants for universities, a new paradigm needs to be developed for financial sustainability of postgraduate professional education to better ensure the growth and development of a strong U.S. engineering workforce in industry (who are the primary generators, developers, and leaders of the nation's future innovative technology for competitiveness and national security). Because of tight university operating budgets and the present emphasis on attracting external funding for scientific research, it is unrealistic to think that existing university funding schemes will implement and sustain new innovative postgraduate programs that focus on the practice of engineering and technology in industry for advanced development and innovative leadership of technology.

   - ***Create new financial paradigm for long-term sustainability.*** Although adequate physical resources that are needed for implementing new high-quality postgraduate programs for the nation's professional practitioners already exist within most U.S. universities, adequate financial support for long-term sustainability for postgraduate education doesn't exist. New financial support must be developed that focuses on long-term sustainability of postgraduate programs across the U.S. from an interdependent industry/government perspective that clearly recognize the long-term local, regional, statewide, and national impact that postgraduate professional education in engineering and technology plays for continuous enhancement of U.S. competitiveness and national security. Support for sustainability must focus on four issues, which are quite cost-effective in order to allow this unique educational innovation to occur for the nation's benefit. They include:

a) Support for practicing graduates (salary of employees/tuition reimbursement paid by industry)
b) Support for faculty development (university/industry)
c) Support for basic infrastructure for start-up and continuous improvement (industry/government)
d) Support for operations (university)

8. Implement Among Coalition Universities and Industry Collaborative Partnerships that Foster Local, Regional, and Statewide Clusters of Engagement, Innovation and Postgraduate Learning Across the Nation as Foundations of U.S. Competitiveness

- ***New paradigms for university-industry engagement.*** Postgraduate programs should focus on developing new paradigms for university-industry engagement that purposefully integrate high-quality postgraduate professional education with the creative technology development and scientific research needs of local, regional, and statewide industry thereby immediately growing the U.S. innovation system for world-class competitiveness.

- ***Connecting postgraduate professional education to development needs of industry.*** High-quality postgraduate professional education in engineering has the potential in helping the fullest development of local, regional, and statewide clusters of industrial-university innovation across the nation "as foundations of U.S. competitiveness." The concept integrates three synergistic mechanisms for this engagement:

a) ***Human resource development to ensure a strong U.S. engineering workforce.*** Enhances the creative and innovative capacity of local, regional, and statewide human resources in the nation's engineering workforce for leadership of world-class technological innovation for sustained U.S. competitiveness and economic growth.

b) ***Directed technology development projects.*** Connects postgraduate professional education directly to the on-going technology development needs of local, regional, and statewide technology-based industry. Develops new innovative technology directly relevant to the needs of sponsoring industry as a direct outcome of project-based learning at the graduate level. It is expected that each participating coalition institution can attract a continuous graduate student enrollment of 100 experienced practicing engineers per year. Hence, this new mechanism for engagement can yield 100 new competitive technology development projects per year per institution; amounting to 500 new technology development projects for five states. Based on future expansion in all 50 states, this unique concept has the potential for implementing over 5000 new innovative technological developments across the country per year that can place U.S. competitiveness and the development of the U.S. engineering workforce second to none.

c) ***Directed strategic scientific research investigations.*** Connects university scientific research investigations directly to the on-going technology development needs of local, regional, and statewide technology-based industry.

Appendix C

Correlating Framework for Integrated Postgraduate Programs that Support Tasks, Responsibilities and Professional Growth for the Practice of Engineering and Leadership of Technology

---

_

Matrix of Skill Sets and Responsibility Levels
Representative of Technology Leadership at Every Level of Engineering Practice

Level Tasks and Responsibilities	Eng. I/II	Eng. III	Eng. IV	Eng. V	Eng. VI	Eng. VII	Eng. VIII	Eng. IX
7: Policy Making and Value Judgment					X	X	X	X
6: Program Making and Strategic Thinking					X	X	X	X
5: Problem Finding and Visualization				X	X	X	X	X
4: Professional Leadership			X	X	X	X	X	X
3: Professional Responsibility		X	X	X	X	X	X	X
2: Creative Problem Solving and Innovation		X	X	X	X	X	X	X
1: Technical Competence	X	X	X	X	X	X	X	X

Appendix D

Guidelines for Curriculum Development for Integrated Postgraduate Programs that Support the Practice of Engineering and Leadership of Technology At the Master of Engineering Level

---

_

Postgraduate Professional Education (Level IV Engineering)
Technology Leaders Program - Master of Engineering (M.Eng.)
Technology Development, Innovation/Project Leadership

Entrance Requirements:

High-quality postgraduate professional master's programs should be formulated to enable experienced working professionals to enter them at a career stage in engineering practice when the additional learning experience would be most valuable. It is now understood that the integrative combination of practical engineering experience plus further advanced studies is a valuable component of an engineer's postgraduate professional education beyond the baccalaureate. Thus, because of the progressive characteristics of professional maturation that are required for those engineers who are pursuing career paths in engineering practice oriented toward the development and leadership of technological innovation, it is recommended that a minimum of three to five years of professional experience in engineering beyond a four-year undergraduate education in engineering or technology from an ABET accredited institution should be required for entrance into these programs. Completion of the FE for progression toward licensure is also recommended.

Expectations:

- This should be a two or three-year postgraduate program that is project-based and designed to concurrently further the professional growth of experienced working professionals beyond entry level in industry and government service on a continuous learning basis while they are fully employed. The program should be designed to concurrently support the engineer's on-going work and leadership of technology development by combining advanced studies and professional practice in a synergistic fashion.

- The program should be designed to meet identified needs and skill sets of high caliber engineering and technology graduates who are assuming career paths and responsible roles in engineering practice for technology development and leadership of innovation relevant to their corporate engineering mission. The program should be designed to further the growth of experienced engineers for progressive levels of attainment as independent investigators, integrative systems developers, and innovators for responsible charge of meaningful engineering project work.

- The program should be designed to foster the development and continued growth of creative engineers who can contribute to the creation, continual improvement, and growth of technology-based systems, operations, products, and processes on which regional economic development depends for creation of new wealth and employment. The program is designed for those engineers who can make original contributions to technology development through purposeful improvement, and by their creative work add to the body of technological knowledge as leaders of the region's and nation's technological progress.

Integrated Curriculum:

Whereas traditionally the engineer's basic undergraduate education is based predominantly on the transmission and acquisition of knowledge from teacher to student for postponed application, at the advanced level the engineer's postgraduate professional education must be transformed to also include the development of the working professional's unique talents and intrinsic potential for increasing self-directedness, industrial creativity, inventiveness, and leadership skills with professional responsibility for immediacy of application and creative work. Accordingly, postgraduate professionally oriented curriculum must be purposefully designed from a holistic or "systems approach" to include necessary breadth and depth in the actual context of engineering practice and leadership of technology development that further develops and builds upon the professional's knowledge base and skill sets that integrates five major ingredients:

- Knowledge and skill sets acquired by undergraduate education in engineering
- An already proven/established competency base in a technological field in industry
- On-going experiential-based learning in engineering practice
- Self-directed learning and inquiry which is necessary to gain technological expertise in the practitioner's field for further creative technology development and innovation
- Project-based learning through actual performance in creative-engineering leadership of substantive technology development project work
- Plus

12 Credit Hours	Core Professional Courses: Emphasis on the dimensions of professional practice at the professional leadership, professional responsibility, and creative problem solving levels of engineering practice. (Four Professional Courses)
12 Credit Hours	Technical Electives: Enhancing the capability for the participant to tailor his/her own program relevant to the participant's field of technology to be selected by the participant with approval of oversight committee; including self-directed learning and independent study in special topics, as well as formal courses/modules. (Three Technical Elective Courses)
12 Credit Hours	Directed Technology Development Project/Thesis: A quality tangible experience of meaningful significance that is directly relevant to the technology development needs of sponsoring industry. This work should represent innovative development at the project leadership level wherein the

participant is in responsible charge.
(Two to Three-Year Effort)

36 Credit Hours

Postgraduate Professional Master's Programs for Engineering Practice/Technology Leadership

- *Aims of postgraduate professional Master of Engineering (M.Eng.) programs for innovative practice*:

  a) Postgraduate professional Master of Engineering programs provide a very practical approach to continuous lifelong learning, a credible and recognized professional degree, and an integrated approach that combines further advanced studies with actual experience and engagement in real-world creative technology development.

  b) Postgraduate professional M.Eng. Programs should emphasize "innovation-learning-practice" by enhancing work-related professional and technical skills that are required for progressive levels of attainment from entry level to Level IV Engineering [6] for responsible technology project leadership.

  c) These programs recognize postgraduate education as a facilitating growth process wherein progressive professional experience, tangible project-based learning, and further advanced studies all serve as integral components of a professional's lifelong growth process

  d) Postgraduate professional M.Eng. Programs should be designed to be concurrent with the working professional's on-going work in engineering and creative technology development. Residency is viewed as residency in the professional's work in industry or government service. The programs enable the working professional to continuously learn, grow, and develop while he/she is fully employed without disrupting the participant's normal work activities or uprooting home, family, or career to continue high-quality postgraduate professional education in engineering.

- *Target participant level for postgraduate professional master programs:*

  a) Practicing leaders of technology with three to five years of experience who are actively involved in innovative technology development in industry or government service.

  b) These programs are designed for experienced engineers in industry and government service who are pursuing career paths that are not centered on research but are centered on the systematic creation, development, and leadership of new innovative technology in the form of new and improved products, processes, systems, or technical operations.

- *Expected outcomes for participant engineers:*

  a) Participants are expected to emerge from the program with the skill-sets, knowledge, and experience ready to assume the responsibilities associated with Level IV Engineering for technology project leadership.

  b) Participants emerging from the program are expected to be fully competent engineers in all-conventional aspects of the subject matter of the functional area of the assignments.

- *Scope of technology project work and expected outcomes:*

  a) Technology development projects are selected to be directly relevant to significant needs of the participant's sponsoring industry and are selected by the participant with the approval of an oversight committee.

b) Projects are selected to provide the participant a meaningful experience at Level IV Engineering of technology project leadership and are expected to result in substantial improvements in products, processes, systems, or operations to the participant's sponsoring industry.

c) Projects are expected to result in original contributions in the body of technical knowledge, which are of benefit to the advancement of the practicing profession.

Appendix E

Guidelines for Curriculum Development for Integrated Postgraduate Programs that Support the Practice of Engineering and Leadership of Technology At the Doctor of Engineering Level

---

_

Postgraduate Professional Education (Level VI Engineering)
Technology Leaders Program – Doctor of Engineering (D.Eng.)
Technology Development, Innovation/Program Leadership

Entrance Requirements:

High-quality professional doctoral programs should also be formulated at the postgraduate level to enable experienced professional engineers to continue their further development in engineering practice beyond the professional master's level. Accordingly, it is now understood that further progressive engineering experience and responsibility beyond the professional master's level plus further advanced studies is a valuable component of an engineer's professional education and lifelong growth process. Thus, because of the increasingly professional maturity characteristics that are required for those engineers who are pursuing career paths in engineering practice oriented toward the development of significant technological innovation at senior levels of engineering responsibility and leadership, it is recommended that a minimum of at least ten years of progressive experience in relevant engineering practice and completion of the professional Master of Engineering or equivalent, and licensure as a Professional Engineer, should be required for entrance into these doctoral programs.

Expectations:

- This is a four-year postgraduate program that is designed specifically to further the continued professional growth of qualified experienced engineers and technologists beyond the professional master's level on a continuous basis while employed full-time in industry or government service. The program is designed to concurrently support the senior engineer's on-going leadership of technology development by combining advanced studies and practice in a synergistic fashion.

- The program is designed to meet identified needs of senior engineering leaders who are assuming career paths of increasingly responsibility for leadership of technology development and innovation relevant to their corporate mission in engineering.

- Whereas traditional doctoral programs are rightfully research-oriented and emphasize a specialized depth of scientific understanding and the development of research capability, with prime emphasis on original contribution to scientific knowledge, it is now understood that doctoral programs in engineering must also be established that are broader in scope with different purpose for those high caliber engineers and technologists who are pursuing career paths that are not centered on research but rather are centered on the development and leadership of technological innovation to meet real-world industrial or social needs through purposeful and deliberate creative engineering innovation.

- The objectives of high-quality professionally oriented doctoral programs in engineering are different from those of academic orientation for research because of the distinction between mission, purpose, and responsibilities required between scientific research and that of creative engineering practice at the highest levels of professional proficiency. Thus, the objectives of professionally oriented doctoral programs for the practice of engineering and leadership of technology development include specifically the further development of the experienced engineer's or technologist's capabilities for conceptual design, advanced development, systems integration, and leadership of innovative technology with technical judgment and professional responsibility within economic and other constraints required for the purposeful development of complex systems, operations, products, or processes that are responsive to real-world needs to improve the human condition.

- The program is designed to further the growth of experienced engineers and technologists as independent investigators, developers, and innovators for increasingly responsible charge of major/significant engineering works.

- The program is designed to foster the development of new innovative technology while simultaneously continuing the growth of senior, experienced engineers and technologists who can contribute to the creation, continual improvement, and growth of major technology-based systems, operations, products, and processes on which regional economic development depends for creation of new wealth and employment.

- The program is designed for those experienced, senior engineering who can make original contributions in systematic technology development for constant innovation and as a resulting outcome of their the leadership and creative work add to the body of technological knowledge as responsible leaders of the region's and nation's technological progress.

- The postgraduate professional Doctoral program is concurrent with the participant's engineering practice and leadership of technology development in industry or government service. The emphasis shifts from classroom instruction to increasing self-directedness, leadership of relevant technology development programs and the integrative combination of progressive engineering experience, postgraduate studies, and actual leadership of on-going creative technology development and innovation in industry.

Integrated Curriculum:

- Further Experiential-Based Learning in Engineering Practice
- Already Proven/Established Competency Base in a Technological Field
- Plus

12 Credit Hours	Core Professional Courses: Emphasis on the dimensions of professional practice at the policymaking, program making, problem finding, and professional leadership levels of engineering practice. (Four Professional Courses)
6 Credit Hours	Technical Electives: Individually tailored program relevant to the participant's field of technology. (Two Elective Courses)
18 Credit Hours	Directed Technology Development Project/Thesis: A quality tangible experience of meaningful significance that is directly relevant to the technology development needs of sponsoring industry. This work should represent innovative technology leadership at the level of technology program making for the sponsoring organization. (Two - Four Year Effort)
36 Credit Hours	

· *Aims of the postgraduate professional Doctor of Engineering (D.Eng.) program for innovative practice:*

a) Postgraduate professional Doctor of Engineering programs provide an alternative to the traditional research-based PhD, being specifically designed to meet the needs of the practicing profession in industry and providing a more professionally oriented doctorate in engineering.

b) Postgraduate professional D.Eng. Programs should emphasize "innovation-learning-practice" by enhancing work-related professional and technical skills that are required for progressive levels of attainment to Level VI Engineering [7] for responsible technology program leadership.

c) These programs recognize postgraduate education as a facilitating growth process wherein progressive professional experience, tangible project-based learning, and further advanced studies all serve as integral components of a professional's lifelong growth process (See Appendix B, D).

d) Postgraduate professional D.Eng. programs should be designed to be concurrent with the working professional's on-going engineering practice and leadership of technology development in industry or government service. The programs will enable the working professional to continuously learn, grow, and develop beyond the master's level while he/she is fully employed without uprooting home, family, or career to continue high-quality postgraduate professional education in engineering.

- *Target participant level for postgraduate professional doctoral program:*

a) Senior leaders of technology with 10+ years of experience who are actively involved in innovative technology development in industry or government service.

b) These programs are designed for experienced, senior engineers and technologists in industry and government service who are pursuing career paths that are not centered on research but are centered on the systematic creation, development, and leadership of new innovative technology in the form of new and improved products, processes, systems, or technical operations.

c) As a flexible professionally oriented program for innovative practice, the Doctor of Engineering (D.Eng.) is designed for those high-caliber engineers/technologists who are pursuing development oriented technology leadership careers in industry or government service as strategic generalists in responsible charge of complex/multidisciplinary functional/corporate engineering areas of technological development and innovation responsibility.

d) These programs are specifically designed for holders of the M.Eng. (or equivalent) with required experience (10+ years) and maturity level who are growing as engineer-leaders of technology.

- *Expected outcomes for participant engineers and technologists:*

a) Participants are expected to emerge from the program with the skill-sets, knowledge, and experience ready to assume the responsibilities associated with Level VI Engineering for technology program leadership.

b) Participants emerging from the program are expected to be fully competent engineer-leaders in all-conventional aspects of technology program leadership responsibility.

- *Scope of technology project work and expected outcomes:*

a) Technology development projects are selected to be directly relevant to significant needs of the participant's sponsoring industry and are selected by the participant with the approval of an oversight committee.

b) Projects are selected to provide the participant a meaningful experience at Level VI Engineering of technology program leadership and are expected to result in substantial improvements in products, processes, systems, or operations to the participant's sponsoring industry.

c) Projects are expected to result in original contributions in the body of technical knowledge, which are of benefit to the advancement of the practicing profession.

Appendix F

Guidelines for Curriculum Development for Integrated Postgraduate Programs that Support the Practice of Engineering and Leadership of Technology At the Engineering Fellow Level

---

Postgraduate Professional Education (Level VIII Engineering)
Technology Leaders Program – Fellow Level of Engineering
Technology Development, Innovation/Policy Leadership

Entrance Requirements:

High-quality postgraduate fellow programs should also be formulated to enable experienced professional engineers and technologists to continue their further growth in engineering practice beyond the professional doctoral level. It is now understood that leadership development in engineering practice is a lifelong growth process that does not end at the doctoral level. Thus, because of the increasingly professional maturity characteristics, skill sets, and responsibilities that are required for those engineers and technologists who are pursuing career paths in engineering practice, beyond the doctoral level, oriented toward senior levels of policy responsibility and corporate leadership, it is recommended that a minimum of at least 15 years of progressive experience in relevant engineering practice, completion of the professional Doctor of Engineering (D.Eng.) or equivalent, and licensure as a Professional Engineer, should be required for entrance into these programs.

Expectations:

- This is a two to four-year postgraduate program that is designed to further the professional growth of senior experienced working professionals on a continuous basis beyond doctoral level while fully employed in industry or government service.

- The program is designed to meet identified needs of senior engineering executives and technology leaders who are assuming career paths of increasingly responsibility for leadership of technology development, innovation, and technology policy making relevant to their corporate mission in engineering.

Integrated Curriculum:

This program takes the practicing professional at the postgraduate doctoral level to the highest senior levels of strategic policy leadership and technical corporate program making. Study is concurrent with the participant's engineering practice in industry or government service. The emphasis shifts from classroom instruction to leadership of technology development policy issues, future directions in engineering practice, and needs-driven technological innovation. Thus, the curriculum is holistically designed using a "systems approach" to include necessary breadth and depth in the context of advanced engineering practice and leadership of technology that integrates six major ingredients:

- Continues to Focus on Experiential Learning in Engineering Practice and Technology Leadership

- Broadens an Already Proven/Established Competency Base in a Technological Field

- Places Emphasis on Further Development of the Participant's Creative, Innovative, and Leadership Potential to Develop Broad Aspects of Strategic Policy Leadership and Engineering Judgment for Responsible Socio-Economic Impact

- Plus

6 Credit Hours	Advanced Seminars: Emphasis on the dimensions of professional practice at the levels of executive policymaking, strategic planning, and corporate engineering responsibility.
6 Credit Hours	Independent Studies
18 Credit Hours	Directed Technology Development Project/Thesis: A quality tangible experience of significant attainment that is directly relevant to the corporate technology leadership of the sponsoring industry. This work should represent Innovative technology leadership at the level of a white paper setting technology policy for the sponsoring organization. (Two - Four Year Effort)
30 Credit Hours	

Postgraduate Professional Fellow Programs for Engineering Practice/Technology Leadership

- *Aims of postgraduate professional fellow programs for innovative practice:*

  a) Postgraduate professional Engineering Fellow programs provide a very practical approach that enables further professional growth beyond the D.Eng./PhD, being specifically designed to meet the needs of the practicing profession in industry at the highest levels of engineering and technology leadership within the practicing profession.

  b) Postgraduate professional Fellow Programs should emphasize "innovation-learning-practice" by enhancing work-related professional and technical skills that are required for progressive levels of attainment beyond Level VI Engineering for responsible technology program leadership.

  c) These programs recognize postgraduate education as a facilitating growth process wherein progressive professional experience, tangible project-based learning, and further advanced studies all serve as integral components of a professional's lifelong growth process (See Appendix B, E).

  d) Postgraduate professional Fellow Programs should be designed to be concurrent with the working professional's on-going engineering practice and leadership of technology development in industry or government service. The programs will enable the working professional to continuously learn, grow, and develop beyond the doctoral level toward their fullest creative, innovative, and leadership potential in responsible charge of significant corporate technological endeavors while he/she is fully employed without uprooting home, family, or career to continue high-quality postgraduate professional education in engineering.

- *Target participant level for postgraduate professional fellow programs:*

  a) Senior executive leaders of technology with 15+ years of experience who are actively involved in innovative technology development in industry or government service.

  b) As a flexible professionally oriented program for innovative practice, the Engineering Fellow programs should be designed for those senior executive, high-caliber engineers/technologists who are pursuing development oriented technology leadership careers in industry or government service as strategic generalists, technology policy leaders, and senior executive engineers in responsible charge of complex/multidisciplinary functional/corporate engineering areas of technological development, innovation responsibility, and technology policy leadership.

  c) These programs are specifically designed for holders of the D.Eng. (or equivalent) with required experience (15+ years) and maturity level who are growing as senior executive engineer-leaders of technology.

- *Expected outcomes for participant engineers and technologists:*

  a) Participants are expected to emerge from the program with the skill-sets, knowledge, and experience ready to assume the responsibilities associated with Level VIII Engineering [8] for technology program leadership.

  b) Participants emerging from the program are expected to be competent senior engineer-leaders in all aspects of technology policy leadership and corporate technological responsibility.

c) Postgraduate Engineering Fellow programs provide a very practical approach to continuous lifelong learning, a credible and prestigious recognition, and an integrated approach that combines further advanced studies with actual experience that emphasizes “innovation and learning” by enhancing work-related professional and technical skills that are required for progressive levels of attainment beyond doctoral level through Level VIII Engineering for responsible senior technology leadership.

- *Scope of technology project work and expected outcomes:*

a) Technology development projects are selected to be directly relevant to significant needs of the participant’s sponsoring industry and are selected by the participant with the approval of an oversight committee.

b) Projects are selected to provide the participant a meaningful experience at Level VIII Engineering of technology program leadership and are expected to result in substantial improvements in products, processes, systems, or operations to the participant’s sponsoring industry.

c) Projects are expected to result in original contributions in the body of technical knowledge, which are of benefit to the advancement of the practicing profession. At level VIII Engineering of strategic planning and technology policy making, the Engineering Fellow is expected to set the corporate culture, vision, and leadership of change that promotes innovative technology development for creativity and innovation to flourish for competitive advantage.