Framework for Integrating Project-Based Learning, Experience and Practice in Professional Graduate Education for Engineers in Industry Leading to the Professional Master of Engineering


Western Carolina University 1 / University of South Carolina 2 / Arizona State University East 3 Morgan State University 4 / California Polytechnic State University 5 / Purdue University 6 New Jersey Institute of Technology 7 / Rochester Institute of Technology 8 Raytheon Missile Systems 9 / Lockheed-Martin Company 19 Boeing Company 11 / Engineering Partnership-Arizona 12 Hewlett-Packard 13 / Rolls-Royce Corporation 14

Abstract

This is the second of four papers prepared for a special panel session of the National Collaborative Task Force on Engineering Graduate Education Reform. The paper formulates a creative approach and framework for postgraduate professional education that fosters continuous development of the U.S. engineering workforce concurrently with engineering practice for technological innovation. The framework integrates innovative project-based learning, progressive experience, self-directed learning, and graduate studies concurrently with engineering practice leading to the professional Master of Engineering (M.Eng.) for early career development of engineering leaders. The intent is to build clusters of postgraduate professional education across the country that strengthens industry’s innovative capability for continuous technology development to enhance U.S. competitiveness.

1. Introduction

The purpose of this paper is to report on the progress of the National Collaborative Task Force on Engineering Graduate Education Reform in reshaping practice-oriented, postgraduate professional engineering education to enhance the U.S. engineering workforce for competitiveness. The National Collaborative Task Force is embarking on an ambitious effort to create centers for postgraduate professional education that better serve the needs of the U.S. engineering workforce in industry for leadership of creative technology development & innovation to strengthen the nation’s innovative capacity for competitiveness. The National Collaborative was formed as a joint initiative of the ASEE-Graduate Studies Division (GSD), College Industry Partnership Division (CIP), and Corporate Members Council (CMC) to implement sustainable reform. The intent of this stage of work is to set the educational framework for high-quality postgraduate education for the professional Master of Engineering (M.Eng.).

2. Professional Education for Engineers in Industry — The New Challenge

If the U.S. is to remain preeminent in creating new innovative technologies through engineering to enhance our economic prosperity, quality-of-life and national security, the U.S. system of engineering education must remain the world’s leader, new models for professional, practice-oriented graduate education must be created that better support lifelong development needs of the U.S. engineering workforce in industry for leadership of creative technology development & innovation to strengthen the nation’s innovative capacity for competitiveness. The National Collaborative was formed as a joint initiative of the ASEE-Graduate Studies Division (GSD), College Industry Partnership Division (CIP), and Corporate Members Council (CMC) to implement sustainable reform. The intent of this stage of work is to set the educational framework for high-quality postgraduate education for the professional Master of Engineering (M.Eng.).

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2.1 A Call-for-Action to Secure U.S. Innovative Capacity and Capability

As the Committee on Science, Engineering, and Public Policy (COSEPUP) has pointed out, engineering graduate education has evolved in the United States primarily as a byproduct of a national science policy for basic research.\(^1\) The United States does not have a coherent policy for the graduate development of the majority of its domestic engineering workforce in industry whose professional careers are not centered on basic research, but rather are centered on the purposeful engineering creation, development & innovation of new/improved/breakthrough technology responsive to market needs.

The neglect of graduate education for practicing engineers has contributed to the long-term decline of U.S. competitiveness. One reason is because many engineering departments/schools have not fully engaged practicing engineers while they are primarily tasked with the development of industry’s new technology for competitive advantage. As Lester Thurow pointed out: “Technological leaders remain economic leaders; technological laggards become losers.”\(^2\) The generation of experienced engineers who have led much of the development of U.S. technology since Sputnik are now retiring. By the year 2010, estimates indicate that 30% of America’s domestic engineering leadership base will have retired, causing a “brain drain” and a loss in U.S. engineering capacity. Our future leaders in industry and government service are not being trained adequately to achieve engineering leadership positions. U.S. graduate engineers in the domestic workforce must be provided the opportunity for a new type of professional graduate education throughout their professional careers.

As the Council on Competitiveness has pointed out, “The United States could lose its preeminence in technology unless a new national innovation agenda is developed.” For the innovation-driven economy to work, the vast majority of technological innovations are needs-driven and market-focused. Subsequently, most of the nation’s technology is created, developed & innovated in industry by its engineers. But the practice of engineering has changed substantially from U.S. science policy originating in 1945.\(^3\)

Engineering in the 21st century is needs-driven and requires purposeful creativity, problem-solving, and responsible leadership for systematic innovation, which must be continuous. Thus, broad sweeping changes are required to create a new type of graduate education (as a complement to research-based graduate education) that is innovation-based and professionally-oriented to better support the further graduate development needs of the U.S. engineering workforce in industry for leadership of technology development & innovation for competitive advantage. For America to compete, we must rebuild its innovative engineering capacity for systematic technology development as a core competence in industry. Advancement in U.S. engineering graduate education is a key to industry regaining its competitive edge.

2.2 Meeting the Challenge for Change – Creating a National Collaborative with Industry

To initiate these necessary broad sweeping changes, the ASEE-Corporate Members Council, Graduate Studies Division, and College Industry Partnership Division have established a National Collaborative for Engineering Graduate Education Reform, comprised of leaders from the universities and industry, to serve as a catalyst for action. Major systemic reform in engineering graduate education must begin by establishing new innovative graduate programs in professional engineering practice for leadership of technology development & innovation in industry.

This is a bold initiative and an exciting new advancement in partnering professionally-oriented engineering graduate education with the practicing profession in American industry that will stimulate technological innovation and regional economic growth across the country. Without continuous technological advancements through creative engineering practice and innovation in industry, no amount of achievement in fundamental scientific progress can assure our economic prosperity and national security in the innovation-driven economy in the modern world.

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3. Urgency for Developing a World-Class U.S. Engineering Workforce for Innovation: 
The Driving Force for Transforming Engineering Education to Improve U.S. Competitiveness

As the American Association for Engineering Education (ASEE) points out — “America’s progress has been synonymous with innovation. Corporate growth and economic development, coupled with a higher standard of living, are inextricably tied to technological advancement. To continue to grow, however, the United States needs a technically literate society and an engineering-mined workforce. Unfortunately, these are two key areas in which our education system often fails to meet the mark.”

3.1 U.S. Engineering Workforce Development: 
Building the U.S. Pipeline for Creativity, Innovation, and Leadership of Technology Development

Today, the education of an engineer must be perceived as a lifelong growth process of professional learning and professional development of “unique intellectual potential” for creativity, innovation, and responsible leadership. The development of creative talent for the practice of engineering must begin in the early years of K-12, but it must also continue through the productive years of advanced engineering practice in industry if creativity, innovation, and leadership is to flourish for the nation’s competitiveness.

The education of engineers is neither limited to a one time experience to be completed in the early years of young adult growth, nor does engineering education terminate at the undergraduate level. As Robert Spitzer, former vice president of Boeing, pointed out: “It never has been possible to teach bachelor’s level individuals everything they will ever need to know. The educational system, however, has behaved for many years as if this were a possible achievement. EC 2000 formally recognizes that this educational model is not feasible.”

As America competes in the 21st century, the National Collaborative Task Force recognizes that there is a strong correlation between the further development of the nation’s graduate engineers and the further development of the nation’s innovative capacity for continuous technology development & innovation. As the nation’s engineers grow and develop professionally, the nation’s capacity for innovation and competitiveness increases proportionally.

3.2 Professional Education through Progressive Career Stages for Engineering Leadership

Further professional education of U.S. engineers in industry, beyond the baccalaureate, is vital to the nation’s continuous creation, development & innovation of new/improved/breakthrough technology. The engine for U.S. economic prosperity, national security, and global competitiveness is the creative and innovative capacity of the U.S. engineering workforce in industry.

As the Council on Competitiveness has pointed out:

“The Council’s business leaders agree that every company’s most important asset are 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.”

Whereas undergraduate engineering and technology education serves as the basic preparation for entry into engineering practice, the National Collaborative Task Force recognizes that progressive experience, actual creative performance in engineering practice, self-directed learning, and further graduate studies are all necessary for the engineer-leader to reach his/her fullest creative, innovative, and leadership potential for technology development and innovation.
3.3 Professional Development in the Early Stages: From Novice to Competent Professional in Engineering Practice

The Task Force recognizes that the education of engineers as professionals is a career long process of professional development of creative, intellectual, and leadership potential that extends from entry-level through Chief Engineer level. Whereas the central theme of this unique educational transformation is to foster the advancement of professional graduate education for engineering practice and technology leadership as a developmental process of professional maturation and lifelong learning, the National Collaborative Task Force recognizes that there are four primary areas of responsibility for leadership development in engineering. They include:

- Early career development in engineering for technology development & innovation
- Middle engineering leadership levels for technology development & innovation
- Senior engineering leadership levels for technology development & innovation
- Executive engineering leadership levels for technology development & innovation

3.4 What is the Difference between the Professional, Practice-Oriented M. Eng. and the Research-oriented M. Sc.?

Whereas high quality graduate education for competent scientific researchers must be integrative with the context of active scientific research (yielding tangible scientific results), high quality professional graduate education for competent engineers must be integrative with the context of active engineering practice (yielding tangible technological results).

While master’s level programs have been underway in the U.S. for some time, a new innovation is emerging in practice-oriented, professional engineering and technology education as a direct outcome of the joint industry-university National Collaborative Task Force on Engineering Graduate Education Reform. Although most master’s programs have been designed as an offshoot of research-oriented graduate programs to prepare young graduate students for research, the practice-oriented professional master of engineering (M.Eng.) should be designed to be a two-year postgraduate professional degree program specifically intended to further the growth of the nation’s development engineers who are already employed full-time in industry, and who show promise as emerging engineering leaders.

The professional master’s of engineering program is a complementary alternative to traditional research-oriented master’s degrees. The practice-oriented professional master’s is specifically designed to support the progressive skill-sets of creative engineering practice in the early stages of the working professional’s career development in industry. Whereas high quality graduate education to develop novices to competent scientific researchers must be integrative with and in the context of active scientific research (yielding tangible scientific results), high quality professional graduate education to develop novices to competent engineers must be integrative with and in the context of active engineering development (yielding tangible technological results).

4. A Work in Progress: Professional Master’s in Engineering

As a result of this initiative, the National Collaborative Task Force is defining specific requirements for the professional master of engineering as a work in progress with industry and universities coming together in this endeavor. The Subcommittee on Framework has put forth sample recommendations which will undergo further modification and refinement. The recommendations are discussed in the next section of our paper.
4.1 Credit Hour Requirements and the Independent Project for the Professional Master’s

The professional Master of Engineering degree (M.Eng.) for the technology leaders program should require a minimum of 30 semester-based credit hours (or 45 quarter credits). All participants (working professionals) are expected to earn at least 24 credit hours of coursework which are acceptable for graduate credit. In addition, a minimum of 6 credit hours toward the degree is earned through work on a directed project that focuses on technology development and builds upon the knowledge and skill-sets acquired through the core and elective courses in the program. The learner’s prior undergraduate engineering education/or engineering technology education, self-directed learning, and expertise acquired through progressive experience in creative engineering practice both beyond entry-level and co-op experience adds to academic experience.

Directed projects are typically a creation or an applied application of technology to solve a business, industrial, or education problem as described by a problem statement and reinforced by a thorough review of the literature. The deliverables or concrete outcomes of a directed project have taken the form of comparative analyses, pilot/prototype systems, software development, physical plant layouts, automatic data capture enterprise solutions, educational and training media, human resource studies, design of experiments studies, multimedia development, and theory of constraints model applications to name just a very few. While the directed project is an academic requirement, students need to use the outcome to affect an organizations’ ability to be more efficient, productive, and creative in maintaining and/or creating new technology economic avenues. Having an opportunity in graduate school to create and objectively follow a detailed data gathering, technology creation, and reporting process is major milestone achievement. The process (the journey) they will go through to gather, collect, create, and report data will last a lifetime and help to better their employer. The examining committee is responsible for determining the acceptability of the work, based upon the significance of the project, the quality and completeness of the written report, the suitability of the oral presentation, and the engineer’s ability to explain and defend the approach, technical details and analysis in the question and answer session following the oral presentation.

Traditionally, all masters level degree programs in engineering require some form of comprehensive examination which not only assesses the acceptability of the participant for the degree but also defines the quality standard for the degree program. For this professional M.Eng. degree, the requirement of a comprehensive examination is satisfied by the successful completion of the written report, oral presentation and defense. As is the case for all research-based advanced degree programs (e.g., the Master of Science with thesis), the level of effort expended by the engineer to successfully complete the technology development project may substantially exceed the amount of time and effort implied by the graduate credit hours assigned to the project. We all must recognize that the quality and ultimate value of the directed project and degree is contingent in large measure upon the standards set for the outcomes of this project.

4.2 Composition of the Examining Committee

Each university partner that offers the Master of Engineering degree is likely to have its own standard practice with respect to the composition of the examining committee and the manner in which the oral presentation and examination are administered. Typically, such examining committees are comprised of at least three faculty members, of which at least two are from within the department/unit that sponsors the degree program. For this specific professional M.Eng. degree program, the examining committee should additionally include a senior manager from one of the participating companies (typically an individual who has some level of leadership responsibility for the degree candidate).
4.3 Focus, Experience in Engineering Practice & Demonstrated Outcomes at Engineer IV

The focus of the professional M.Eng. is to develop engineers in the early stages of their continuous professional development process as leaders in the context of creative engineering practice for systematic engineering innovation to create, develop & innovate new/improved technology continuously in the form of new/improved/breakthrough products, processes, systems, and operations to meet real-world needs. Participants are expected to improve, create, develop & innovate new/improved technology in industry and to develop professionally in engineering practice as Engineer-Leaders with Level IV Engineer skill-sets for responsible leadership of continuous technology development & innovation at project level.

5. Drawing the Right Conclusion: A Work in Progress in Implementing the U.S. Innovation Agenda for Competitiveness

There is a strong need for the vast majority of the nation’s domestic engineering graduates, in all states across the nation, to have the opportunity to pursue high-quality postgraduate professional education in order to further their development as leaders of U.S. technology development & innovation to enhance competitiveness. A major aim of the National Collaborative Task Force is to provide this opportunity through planned educational change. The National Collaborative Task Force is on-target and steady progress is underway. To accomplish its mission, the Task Force is building a critical mass of leaders from industry, universities, and government to allow this transformation to happen. Once the critical mass is obtained, the progress will become even faster in implementing the innovation agenda for competitiveness. It is a work in progress to enhance the nation’s continuous thrust for technological development & innovation through professional education and creative engineering practice in industry.

References

4. Report of the ASEE K-12 Center, 2004
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Appendix: A - 1

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

<table>
<thead>
<tr>
<th>Stages of Growth</th>
<th>Typical Responsibilities-Autonomy-Judgment</th>
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<tbody>
<tr>
<td>ENGINEER IX</td>
<td>An engineer-leader at this level is in responsible charge of programs so extensive and complex as to require staff and resources of sizeable magnitude to meet the overall engineering objectives of the organization.</td>
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<tr>
<td>ENGINEER VIII</td>
<td>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. Is responsible for deciding the kind and extent of engineering and related programs needed for accomplishing the objectives of the organization.</td>
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<tr>
<td>ENGINEER VII</td>
<td>In a leadership capacity, 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.</td>
</tr>
<tr>
<td>ENGINEER VI</td>
<td>In a leadership capacity, 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.</td>
</tr>
<tr>
<td>ENGINEER V</td>
<td>In a leadership capacity, plans, develops, coordinates, and directs a large and important project or a number of small projects with many complex features. Or, as an individual principle 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.</td>
</tr>
<tr>
<td>ENGINEER IV</td>
<td>Plans, schedules, conducts, or coordinates detailed phases of engineering work in part of a major project or in a total project of moderate scope. Fully competent engineer in all conventional aspects of the subject matter of the functional areas of assignments. Devises new approaches to problems encountered. Independently performs most assignments requiring technical judgment.</td>
</tr>
<tr>
<td>ENGINEER III</td>
<td>Performs work that involves conventional types of plans, investigations, or equipment with relatively few complex features for which there are precedents. Requires knowledge of principle and techniques commonly employed in the specific narrow areas of assignments.</td>
</tr>
<tr>
<td>ENGINEER I/II</td>
<td>Requires knowledge and application of known laws and data. Using prescribed methods, applies standard practices/techniques under direction of an experienced Engineer.</td>
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Appendix: A - 2

Levels of Responsibilities in Creative Engineering Practice for Engineering Leadership of Continuous Technology Development & Innovation In Industry and Government Service

Top Levels of Technology Leadership

Position Title:
Engineer IX (GS-18, 17, 16)
Chief Engineer / Vice President of Engineering & Technology

Engineer VIII (GS-15)
Director of Engineering

Middle Levels of Technology Leadership

Position Titles:
Engineer VII (GS-14)
Department/Division Manager

Engineer VI (GS-13)
Technica Area Manager

First Levels of Technology Leadership

Position Titles:
Engineer V (GS-12)
Senior Engineer/Principal Engineer/Project Leader/Group Leader

Engineer IV (GS-11)
Project Engineer/Process Engineer

Engineer III (GS-9)
Design/Development Engineer

Entry Level Engineer

Position Titles:
Engineer II/I (GS-7, 5)
Entry Level Engineer
Appendix: B - 1

Aims of Professional Master of Engineering (M. Eng.)
Programs for Working Professionals in Industry

Professional Master of Engineering – For Creative Engineering Practice & Leadership
Level IV Engineer –Skill-Sets / Outcomes

- **Aims of professional Master of Engineering programs for engineering practice & leadership**
  a) Professional Master of Engineering (M.Eng.) programs provide a very practical component to lifelong learning; a recognized professional degree; and an integrated approach that combines advanced studies with self-directed learning, progressive experience in engineering practice, and actual engagement in creative technology development & innovation.
  b) High-quality, postgraduate professional M.Eng. programs should emphasize project-based (problem-centered) – “innovation-based learning” – concurrent with creative engineering practice thereby enhancing work-related professional skill-sets required for progressive levels of attainment from entry-level to Engineer IV level proficiency.
  c) Professional M.Eng. programs should support the skill-sets/outcomes required for responsible leadership of significant work at Engineer IV level of project responsibility.
  d) Professional M.Eng. programs should recognize postgraduate education not only as a learning process beyond the baccalaureate, but as a process for continuous professional development of intrinsic human potential, for further development of creativity, innovation, and leadership wherein self-directed learning, progressive experience, tangible project-based learning, and further advanced studies all serve as integral components of a working professional’s lifelong growth process to reach his or her potential for leadership in engineering practice.
  e) Professional M.Eng. programs should be specifically designed to be concurrent with and to support the working professional’s on-going creative work and stage of growth in engineering practice for responsible leadership of creative, systematic technology development & innovation.
  f) Residency should be viewed as residency in engineering practice in the professional’s workplace in industry/government service. Postgraduate professional M.Eng. programs enable the working professional to continuously learn, grow, and develop while he or she is fully employed without disrupting the practitioner’s normal work activities or uprooting home, family, or career to continue high-quality professional education in engineering practice.

- **Target market for professional Master of Engineering programs**
  a) The professional master’s programs in engineering practice & technology leadership should be targeted to enhance the innovative capability of engineers within the U.S. Engineering Workforce (in regional industry across the nation) who are actively engaged in innovative technology development and continuous improvement at project engineering level of responsibility.
  b) The professional M.Eng. programs should be specifically designed to continue the professional education of engineers, after entry into industry, who are emerging as leaders and are pursuing career paths that are not centered on research but are centered on the purposeful, systematic engineering creation, development & innovation of new/improved technology in the form of new/improved/breakthrough products, processes, systems, or technical operations.

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Integrative professional curriculum with engineering practice

a) Whereas, basic undergraduate engineering education prepares young, inexperienced engineers for entry into engineering practice and is predominantly based on a faculty-centered, content-model of instruction focusing on the transmission of knowledge from teacher to student for postponed application, the intent of advanced professional engineering education is to further the continued professional development of experienced engineers beyond entry-level toward their fullest potentials as creative professionals and leaders at the highest levels of leadership responsibility in engineering practice.

b) As such, high-quality professional education should shift from a traditional faculty-centered, content-model of instruction to a learner-centered, process-oriented model of continuous professional development focusing on further development of the working professional’s intrinsic creative, innovative, and leadership potential for increasing self-directedness, inventiveness, and engineering leadership skills for immediacy of application in actual creative engineering work.

c) Professional education should be practice-oriented and designed from a holistic approach that more fully develops the engineer’s breadth and depth in the context of actual engineering practice for leadership of on-going technology development & innovation projects.

d) Professional education for engineers should shift from the traditional perspective of one-time learning to a process of continuous professional development that builds upon the wealth of the working professional’s progressive experience; an already established technical knowledge base; and an already established skill-sets base and competency base in his or her field of technology.

e) Professional M.Eng. programs for working professionals should be specifically designed to build upon six major integrative ingredients. These include:

(1) Knowledge and skill-sets acquired by undergraduate education in engineering.
(2) The engineer’s already established competency base in a technological field in industry.
(3) On-going experiential-based learning in creative engineering practice.
(4) Self-directed learning necessary to gain technological expertise in the practitioner’s field.
(5) Project-based learning in substantive technology development project work.
(6) Planned professional core studies and electives concurrent with practice.

Scope of technology projects and expected project outcomes & impact

a) Technology development projects should be specifically selected to be directly relevant to significant needs of the participant’s sponsoring industry/or of society; and should be selected by the participant with the approval of an oversight committee from industry and the university.

b) Technology development projects should provide the participant a meaningful professional learning experience at Engineer VI level of technical program leadership responsibility and result in substantial improvements in products, processes, systems, or operations to the participant’s sponsoring industry.

c) Technology projects should yield new “ideas and concepts” for creative engineering solutions through proof of feasibility for new technological improvements, developments, and innovations for products, processes, systems, and technical operations or organizational infrastructure that ultimately contribute to the body of new technological knowledge of benefit to the advancement of engineering practice, the participant’s corporate sponsor, and society as a result of this deliberate creative engineering work for constant innovation.

d) Technology development projects should be directed resulting in a project report and a quality tangible experience of meaningful significance that is directly relevant to the technology
development & innovation needs of the participant’s sponsoring industry/or society. This work should represent deliberate creation, improvement, development and innovation at the technical program engineering leadership level wherein the participant is in responsible charge.

- **Expectations of skill-sets / outcomes for participant Engineer-Leaders**

  a) The professional master’s program should be a two-year postgraduate program, which is integrated concurrently with engineering practice, that is project-based and is specifically designed to foster the professional growth of experienced working professionals beyond entry-level in industry/government service on a continuous basis while they are fully employed. The program should be designed to nurture the engineer’s leadership of technology development & innovation by combining advanced studies with engineering practice in a synergistic fashion.

  b) The program should be designed to meet the progressive skill-sets of creative engineering practice for ABET graduates (engineering/engineering technology) who are assuming career paths and responsible leadership roles in engineering practice for technology development & 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 full-fledged practitioners, systems developers, innovators, integrators, and leaders for responsible charge of meaningful engineering project work.

  c) The program should be designed to foster the continuous professional development of Engineer-Leaders who contribute to the creation, improvement, development, and innovation of new technology-based systems, operations, products, and processes on which regional industrial growth and economic development depends for creation of new wealth/employment/national security purposes.

  d) The program should be designed for those engineers who can make original contributions to the creation, invention, and development of new/improved technology through purposeful, systematic improvement/breakthrough innovation. And as a result of their creative engineering work, add to the body of new technological knowledge as leaders for the region’s and nation’s technological progress and competitiveness.

  e) Participants are expected to emerge from the professional master’s program as fully competent professionals and experienced Engineer-Leaders in a functional area of the sponsor’s technology with the skill-sets, knowledge, experience, and outcomes ready to assume responsibilities associated with Engineer IV qualifications for technology project leadership.

- **Entrance requirements**

  a) High-quality postgraduate professional master’s programs should be formulated to enable working professionals to enter them at an early career stage in engineering practice/and at later stages of professional development when the additional learning and growth 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 continuing professional education beyond the baccalaureate.

  b) Because many of the skill-sets that are required during the professional maturation process in engineering practice for leadership of technology development & innovation in industry can only be attained through practical experience, it is recommended that a minimum of at least six months of professional experience in engineering practice, beyond a four-year undergraduate education in engineering/engineering technology from an ABET accredited institution, should be required for entrance into these professionally-oriented graduate programs. Completion of the FE for progression toward licensure is also recommended when appropriate.
Appendix: B - 2

Framework: For High-Quality Postgraduate Professional Education Leading to The Professional Master of Engineering that is Integrative with Practice and Enables Lifelong Learning and Professional Development of Engineers as Creative Professionals and Technology Leaders in Industry

Professional Master of Engineering — For Creative Engineering Practice & Leadership
Level IV Engineer – Skill-Sets / Outcomes

Focus: Professional Development of Emerging Engineer-Leaders in Industry
For Creative Technology Development & Innovation at Project Leadership Level

Postgraduate Professional Education Integrative with Creative Engineering Practice

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<tr>
<th>Credit Hours</th>
<th>Component</th>
<th>Description</th>
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<tbody>
<tr>
<td>18</td>
<td>Core Professional Courses:</td>
<td>Emphasis on the professional dimensions / knowledge / critical skill-sets required in engineering practice (at Level IV Engineer) for engineering leadership, professional responsibility, and creative problem solving at project engineering level for technology development &amp; innovation in industry/government service. (Six Professional Courses)</td>
</tr>
<tr>
<td>6</td>
<td>Professional Electives:</td>
<td>Emphasis on flexibility in tailoring program electives to be relevant to the participant’s field of technology/or other professional needs 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. (Two Elective Courses)</td>
</tr>
<tr>
<td>6</td>
<td>Directed Technology Development Project:</td>
<td>Emphasis on gaining real-world experience in creative problem-solving through project-based (problem-centered learning) focusing on innovation through a quality tangible experience of meaningful significance that is directly relevant to the technology development &amp; innovation needs of the participant’s sponsoring industry. This work should represent innovative development at the project leadership level wherein the participant is in responsible charge.</td>
</tr>
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<td>30</td>
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</table>
Appendix: B - 3

Integrative Components: For High-Quality Postgraduate Professional Education Leading to the Professional Master of Engineering with Practice and Enables Lifelong Learning and Professional Development of Engineers as Creative Professionals and Technology Leaders in Industry

Professional Master of Engineering — For Creative Engineering Practice & Leadership
Level IV Engineer – Skill-Sets / Outcomes

Focus: Professional Development of Emerging Engineer-Leaders in Industry
For Creative Technology Development & Innovation at Project Leadership Level

Integrative Components:

- **Curricular Components**
  - 18 cr. Core Professional Modules
  - 6 cr. Elective Modules
  - 6 cr. Technology Development Project
    - In Industry (Focus on Innovation)

  30 cr. Total

- **Professional Maturation Components**
  - a) **Residency Component**
    - Full-time employment in engineering practice in industry/government service
  - b) **Progressive Experience Component Beyond Entry-Level**
    - Minimum of 3 to 5 years of progressive experience beyond entry-level in engineering practice
  - c) **Technical Competency Component**
    - Demonstrated growth from novice to competent professional in a specific technological field

- **Admission Requirements to Program**
  - Graduate of ABET program in engineering / or engineering technology; Minimum of at least 6 months beyond entry-level experience in engineering practice; Level II Engineer; plus strong letters of recommendation from participant’s sponsor / practicing professionals in engineering; and FE when appropriate. The Graduate Record Examination is required by many programs across the country. Minimum scores are set by graduate schools and/or departments offering graduate degrees.