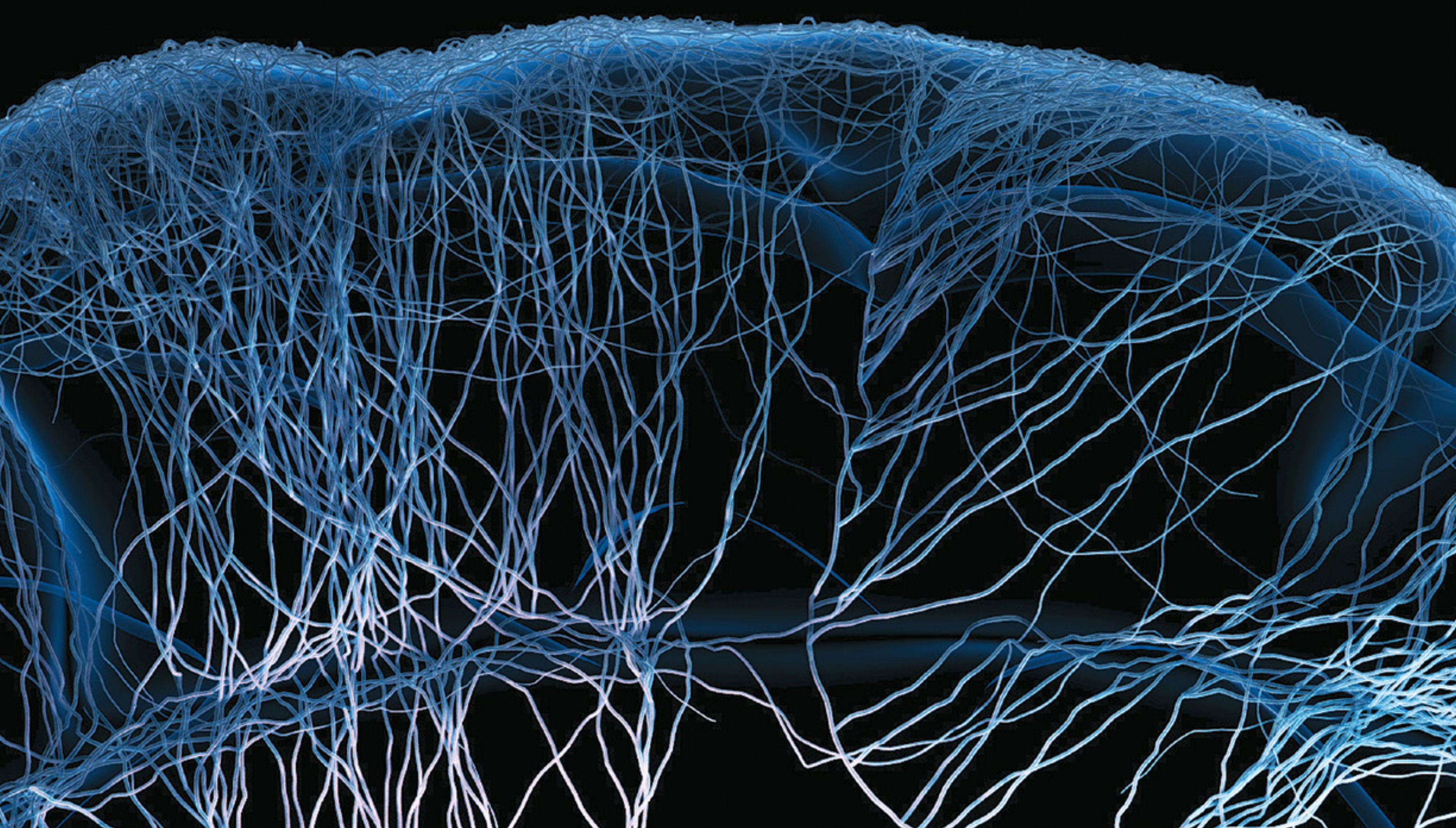
NSPE NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

Professional Engineering Body of Knowledge

Prepared by the Licensure and Qualifications for Practice Committee of the National Society of Professional Engineers

FIRST EDITION, 2013



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Contents

Executive Summary

The National Society of Professional Engineers (NSPE) Engineering Body of Knowledge (BOK) initiative was undertaken in support of the Society's vision, mission, and values and in recognition of the need to proactively prepare for and participate in continuous changes in technological, social, cultural, political, and economic conditions. The charge undertaken by NSPE's Licensure and Qualifications for Practice Committee (LQPC) included reviewing recent key publications and then developing, while interacting with various stakeholders within and outside of NSPE, an Engineering BOK common to all engineering disciplines.

As suggested by the charge and consistent with NSPE's vision, mission, and values, the Engineering BOK project and the resulting report are about the future. Given the uniqueness of this effort, including its future orientation and its intent to encompass all engineering disciplines, this report should be viewed as an aspirational and living document. It stimulated interdisciplinary discussions during its preparation and is expected to encourage continued conversations now that it is published and widely available. Those interactions are very likely to eventually require a subsequent edition of the Engineering BOK.

The Body of Knowledge Concept

A profession's BOK is its common intellectual ground—it is shared by everyone in the profession regardless of employment or engineering discipline. The Engineering BOK, as used in this report, is defined as the depth and breadth of knowledge, skills, and attitudes appropriate to enter practice as a professional engineer in responsible charge of engineering activities that potentially impact public health, safety, and welfare. Within the BOK:

- Knowledge consists of comprehending theories, principles, and fundamentals;
- Skills are the abilities to perform tasks and apply knowledge; and
- Attitudes are the ways in which one thinks and feels in response to a fact or situation.

In broad terms, knowledge is what one knows in a fundamental sense, skill is what one is able to do with what one knows, and attitude is how one responds to a variety of situations.

The Engineering Body of Knowledge

For the purposes of the Engineering BOK, the knowledge, skills, and attitudes are referred to as "capabilities." A capability is defined as what an individual is expected to know and be able to do by the time of entry into professional practice in a responsible role. A given capability typically consists of many diverse and specific abilities.

Each capability is usually acquired by a combination of engineering education and experience. NSPE will not be “teasing apart” what aspects or parts of the capabilities are fulfilled through education or experience because these means may vary significantly across disciplines and employment circumstances.

The names of 30 capabilities comprising the recommended Engineering BOK are listed here. They are organized for clarity into three categories, namely, Basic or Foundational, Technical, and Professional Practice. To reiterate, these are the names of the capabilities. The names are just that, they do not describe the capabilities. Refer to Appendix D for a description of each capability along with examples of supporting abilities.

> *Basic or Foundational Capabilities:* 1. Mathematics, 2. Natural Sciences, 3. Humanities and Social Sciences
>
> *Technical Capabilities:* 4. Manufacturing/Construction, 5. Design, 6. Engineering Economics, 7. Engineering Science, 8. Engineering Tools, 9. Experiments, 10. Problem Recognition and Solving, 11. Quality Control and Quality Assurance, 12. Risk, Reliability, and Uncertainty, 13. Safety, 14. Societal Impact, 15. Systems Engineering, 16. Operations and Maintenance, 17. Sustainability and Environmental Impact, 18. Technical Breadth, 19. Technical Depth
>
> *Professional Practice Capabilities:* 20. Business Aspects of Engineering, 21. Communication, 22. Ethical Responsibility, 23. Global Knowledge and Awareness, 24. Leadership, 25. Legal Aspects of Engineering, 26. Lifelong Learning, 27. Professional Attitudes, 28. Project Management, 29. Public Policy and Engineering, 30. Teamwork

While the full BOK is intended to apply across the engineering profession, each engineering discipline and employment situation combination may focus on a certain subset of the capabilities. Preparing a profession-wide BOK for a profession as diverse as engineering is challenging and worthwhile.

Uses of the Engineering Body of Knowledge

The recommended Engineering BOK can be useful, in a variety of ways, to various members of the profession and those with whom they interact; it is not an abstract concept. More specifically, the Engineering BOK can be of value to prospective and current engineering students, engineer interns and professional engineers, engineering mentors and supervisors, employers, engineering and other faculty, accreditation leaders, and licensing and certification boards.

In preparing, publishing, and widely distributing this document NSPE hopes that individuals, such as those just listed here, and their organizations will be motivated to examine where they have been, are, and could go. More specifically, NSPE asks each engineering discipline to use the Engineering BOK as another means of engaging its stakeholders in assessing the discipline’s status and challenges and then contemplating options for moving forward to meet those challenges.

Chapter 1

Introduction

NSPE's Vision, Mission, and Values

The Vision[1] of the National Society of Professional Engineers (NSPE) is to be "the recognized voice and advocate of licensed Professional Engineers." In partnership with the State Societies, NSPE's Mission[1] is to be "the organization of licensed Professional Engineers (PEs) and Engineer Interns (EIs)" and, the mission goes on to state that "NSPE enhances the image of its members and their ability to ethically and professionally practice engineering" and does this "through education, licensure advocacy, leadership training, multidisciplinary networking, and outreach." NSPE's Vision and Mission are supported by the following eight values[1]:

1. Protection of the public welfare above all other considerations;
2. Ethical and competent practice of engineering;
3. Innovation through the creative application of math, science, and engineering;
4. The PE license as the highest standard of professionalism in engineering;
5. Continuous learning for professional growth;
6. Growth in the number of licensed professional engineers;
7. Teamwork, unity, and fellowship of all PEs across all disciplines; and
8. Commitment to the future of the licensed professional engineer.

The NSPE Engineering Body of Knowledge (BOK) initiative was undertaken in support of the Society's vision, mission, and values. More specifically, the Engineering BOK project as described in this report is linked to and supports all eight values. (Note: Abbreviations used in this report are listed in Appendix A.)

Charge Undertaken by the NSPE Licensure and Qualifications for Practice Committee

In 2011, the Licensure and Qualifications for Practice Committee (LQPC) of the NSPE (see Appendix B) took on the following charge:

- Review the National Academy of Engineering (NAE) book *The Engineer of 2020* and the Civil Engineering and Environmental Engineering BOK reports[2,3,4] and determine which elements of these reports apply to all engineering disciplines;

- Prepare an outline of an Engineering BOK common to all engineering disciplines, with broad topics listed in bullet form, in 2011–12;

- Obtain input on the outline from the NSPE Board of Directors, Professional Engineers in Private Practice (PEPP), Professional Engineers in Industry (PEI), Professional Engineers in Construction (PEC), Professional Engineers in Higher Education (PEHE), and the Legislative and Government Affairs Committee in spring 2012; and

- Confirm the value of preparing an Engineering BOK and schedule its preparation for, at minimum, a two-year 2012–13 process.

As suggested by the charge and consistent with NSPE's vision, mission, and values, the Engineering BOK project and the resulting report are to be about the future, not the present. This aspirational initiative is about tomorrow's engineering practitioners, not necessarily about today's, although many of the capabilities are applicable now for practice as a professional engineer. Undoubtedly, there will be a need for both increased depth and breadth in each of these capabilities in the future. This initiative envisions the capabilities of tomorrow's practicing professional engineers. This project is intended to include all engineering disciplines practiced in the U.S. See Appendix C for a list of engineering disciplines recognized by ABET, the organization that accredits engineering programs.[5]

Finally, given the uniqueness of this effort, including its future orientation and its intent to encompass all engineering disciplines, the resulting report—this document—should be viewed as a living document. It stimulated interdisciplinary discussions during its preparation and is expected to encourage continued conversations as it is disseminated. Those interactions are very likely to continue and to eventually require a subsequent edition of the Engineering BOK.

The Process Used

The Engineering BOK Subcommittee developed a draft Engineering BOK outline which was approved by the LQPC in March 2012 for internal review within NSPE. Comments were solicited from the NSPE Board of Directors, the NSPE Legislative and Government Affairs Committee, and various interest groups within NSPE. Comments received from those reviews and from a blog piece on the NSPE Web site were incorporated into the outline.

Members of the Engineering BOK Subcommittee prepared and presented a webinar[6] about the NSPE Engineering BOK project in June 2012, and input from it was reflected in the Engineering BOK outline. Individuals and organizations, within and outside of NSPE, were invited to send their input to Arthur Schwartz, NSPE general counsel, at aschwartz@nspe.org. Review and comments were invited from engineering societies; comments were received from IEEE-USA, AIChE, ASCE, and ASABE and incorporated into the working outline. ACEC, ASME, ASHRAE, and AAEES were also invited but did not provide comment.

Descriptions of the capabilities and example abilities which had been listed in the working outline were drafted by members of the LQPC in early 2013. The resulting report was reviewed and approved by the LQPC at its March 2013 meeting as an initial draft for external review. Input on the full draft report was solicited from NSPE's interest groups, the NSPE Board of Directors, and engineering societies including those that had provided comments on the working outline. Extensive review comments were received from IEEE-USA, AIChE, ASCE, ASABE, and the Japan Society of Professional Engineers, and that input was incorporated in a final draft for review and approval by the LQPC and the NSPE Board of Directors. The first edition was approved by the NSPE Licensure and Qualifications for Practice Committee at its meeting on July 21, 2013, and by the NSPE Board of Directors at its meeting on October 12, 2013.

The preparation of the NSPE Engineering BOK involved extensive collaboration among many professional engineers of various engineering disciplines. The LQPC members listed in Appendix B include five past presidents of NSPE, two past presidents of NCEES, and 11 members who have served on PE boards in their respective states. The partner engineering societies each staffed the review of these documents with engineers with extensive experience in their engineering disciplines and in licensure. Input was received from mechanical, electrical, industrial, chemical, civil, environmental, structural, and agricultural engineers.

Preparing this engineering body of knowledge was a challenging endeavor. The engineering profession has not had a BOK before, so a format needed to be created. Making the BOK broad enough to apply to all engineering disciplines, as well as all employment situations and engineering roles within those disciplines, represented quite a significant challenge. Comments on this BOK are encouraged and should be forwarded to the NSPE Licensure and Qualifications for Practice Committee, through NSPE General Counsel Arthur Schwartz at aschwartz@nspe.org. Depending on input received, a second edition might be considered in the future.

Chapter 2

The Body of Knowledge Concept

Definitions

A profession's BOK is its common intellectual ground—it is shared by everyone in the profession regardless of employment or engineering discipline. The Engineering BOK, as described in this report, is defined as the necessary depth and breadth of knowledge, skills, and attitudes required of an individual to enter practice as a professional engineer in responsible charge of engineering activities that potentially impact public health, safety, and welfare.

- Knowledge consists of comprehending theories, principles, and fundamentals.

- Skills are the abilities to perform tasks and apply knowledge.

- Attitudes are the ways in which one thinks and feels in response to a fact or situation.

In broad terms, knowledge is what one knows in a fundamental sense; skill is what one is able to do with what one knows; and attitude is how one responds to a variety of situations. For the purposes of this Engineering BOK, the knowledge, skills, and attitudes are referred to as "capabilities" that are necessary for the practice of engineering as a professional engineer. The capabilities are introduced in Chapter 4 and described in detail in Appendix D.

Uses of the Engineering Body of Knowledge

A well-crafted Engineering BOK can be useful, in a variety of ways, to various members of the profession and those with whom they interact; it is not an abstract concept. A BOK is a foundation on which professionals prepare for and build careers and from which they communicate about their profession to others. More specifically, consider the relevance of the Engineering BOK to various members of and stakeholders in the engineering community. With an eye to the future, the Engineering BOK:

- Offers **prospective engineering students**, their parents, and advisors, as well as the general public, a glimpse of the importance of engineering (e.g., guiding principles in Chapter 3); indicates the breadth of knowledge and skills required to practice engineering (e.g., key attributes in Chapter 3 and the capabilities in Chapter 4 and Appendix D); and suggests the breadth of opportunities offered by an engineering career (e.g., sum of the preceding);

- Assists **engineering and other faculty** in designing curricula, creating and improving courses, arranging cocurricular activities, and teaching and counseling students;

- Provides **current engineering students** with a framework within which they can understand the purpose, plan the completion, and measure the progress of their studies;

- Gives accreditation **leaders** guidance for developing appropriate education criteria;

- Informs **employers** what they can expect in terms of basic knowledge, skills, and attitudes possessed by engineering graduates;

- Suggests to **employers** their role, in partnership with individual engineers, in helping them attain the levels of achievement needed to enter the practice of engineering at the professional level;

- Provides **engineer interns** with a comprehensive list of capabilities to assist them in evaluating the breadth and depth of their engineering experience;

- Provides **engineering mentors and supervisors** with a template to assess the breadth and depth of experience being gained by engineer interns, and assists in focusing additional areas of experience that may be required;

- Provides **licensing boards** with an improved ability to evaluate the capabilities of engineers in professional practice which are needed to meet the engineering profession's responsibility to protect public safety, health, and welfare; and

- Encourages specialty **certification boards** to build on the engineering BOK in defining their desired mastery level of achievement.

Chapter 3

The Professional Engineer of the Future

Guiding Principles that Will Shape the Future of Engineering

The five quotations below are guiding principles taken directly from the NAE report *The Engineer of 2020*.[2] The guiding principles following the quotations are proposed by NSPE as additional guiding principles that will shape the future of engineering.

NAE Guiding Principles – *The Engineer of 2020*

- "The pace of technological innovation will continue to be rapid (most likely accelerating)."
- "The world in which technology will be deployed will be intensely globally interconnected."
- "The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever."
- "The population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, and government users) will be increasingly diverse and multidisciplinary."
- "Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation."

NSPE Proposed Additional Guiding Principles

- Engineering practice and professionalism will increasingly require the ability to draw upon a broad and comprehensive body of knowledge to make focused discretionary judgments about optimal solutions to unique, complex problems in the interest of enhancing public health, safety, and welfare.
- Engineers from well-developed countries will increasingly be challenged to provide innovative, higher value-added services and products and to do so in a leading-edge manner.
- As globalization of engineering practice expands, leadership in the ethical practice of engineering and the need to hold paramount public health, safety, and welfare will become more critical.

- Through both education and training, engineers will need a broad background to understand and manage the impact of engineering solutions in a global, economic, environmental, and societal (i.e., sustainable) context.
- The increasing need to incorporate societal impact considerations in engineering decision-making will require better communication, management, leadership, and other professional practice skills on the part of engineers. Collaboration with nonengineers will be critical.
- The rapid and accelerating pace of technological innovation will increase the need for continuing professional development and lifelong learning on the part of engineers.

Key Attributes of the Professional Engineer of the Future

Looking ahead a decade or so, professional engineers will need attributes similar to those that sufficed in the past; however, those attributes will need to be expanded and refined due to inevitable change. More specifically, tomorrow's successful and relevant professional engineer will need the following attributes:

- Analytical and practical;
- Thorough and detail-oriented in design;
- Creative and innovative;
- Communicative;
- Knowledgeable about the application of sciences and mathematics;
- Thoroughly knowledgeable in a selected field of engineering and conversant in related technical fields;
- Knowledgeable about and skillful in business and management;
- Able to provide leadership—with ability to effect change in strategies, tactics, policies, and procedures in project and other roles;
- Professional and positive in attitude;
- Aware of societal and historical considerations in the global context;
- Aware of and compliant with relevant laws, regulations, standards, and codes;
- Licensed as a professional engineer and knowledgeable about engineering ethics and applicable codes of professional conduct; and
- Dedicated to lifelong learning.

Chapter 4

The Engineering Body of Knowledge

Definition of Entry into Professional Engineering Practice

This report uses expressions such as "practice of engineering as a professional engineer," "entry into the professional practice of engineering," "practice as a professional engineer," and "practice of engineering at the professional level." For the purpose of this report, all of these expressions are equivalent to entry into practice as a licensed professional engineer in responsible charge of engineering activities (i.e., projects or components of projects) that potentially impact public health, safety, and welfare.

In this context, responsible charge means activities such as carrying out assignments, making project plans, directing engineering designs, writing specifications, preparing engineering reports, or deciding methods of execution or suitability of materials, all without referring to a higher authority other than for collaborative and/or checking purposes. We are attempting to describe the capabilities and abilities of a professional engineer at the time in their career when they are just beginning to assume responsible charge, perhaps with straightforward project components. According to the NCEES Model Law, responsible charge means "direct control and personal supervision of engineering work." NSPE defines responsible charge as an engineer providing "supervisory direction and control authority."

Use of Capabilities to Describe the Body of Knowledge

As noted in Chapter 2, for the purposes of the Engineering BOK, knowledge, skills, and attitudes are referred to as capabilities that are necessary for entry into the practice of engineering as a professional engineer. A capability is defined as what an individual is expected to know and be able to do by the time of entry into professional practice in a responsible role. A given capability typically consists of many diverse and specific abilities.

Each capability is usually acquired through a combination of engineering education and experience. NSPE will not attempt to "tease apart" what aspects or parts of the capabilities are fulfilled through education or experience because these means may vary significantly across disciplines and employment circumstances.

The capabilities are broadly defined and will have differing priorities in various engineering disciplines and in different employment situations. The abilities are presented as examples, and are precisely that—examples. The specific abilities required in each engineering job, and in each discipline, will vary significantly.

Overview of the Capabilities

The 30 capabilities in the Engineering BOK are summarized in Table 1 where they are organized for clarity in three categories; Basic or Foundational, Technical, and Professional Practice. While the full BOK is intended to apply across the engineering profession, each engineering discipline and employment situation combination may focus on a certain subset of the capabilities. Preparing a BOK for a profession as diverse as engineering is challenging. The table lists the name of each capability, briefly notes its relevance, and gives an example of a supporting ability. The names are just that, they do not describe the capabilities. Refer to Appendix D for a description of each capability along with examples of supporting abilities.

Table 1. Summary of Capabilities Within the Engineering Body of Knowledge

Capability Category	Capability Name and Number	Relevance to the Professional Practice of Engineering	Example of a Supporting Ability
Basic or Foundational	1. Mathematics	Mathematics enables engineers to use logic and calculations to work on practical problems	Apply an appropriate area of mathematics in the planning or design of a portion of a facility, structure, system, or product
	2. Natural Sciences	Physical and biological sciences are the foundation of engineering	Use the laws of science to solve engineering problems
	3. Humanities and Social Sciences	The humanities examine the "what" of human values and the social sciences the "how"	Explain the technical aspects and benefits of an engineering project to nontechnical audiences
Technical	4. Manufacturing / Construction	Manufactured products and constructed infrastructure are a major factor in determining the quality of life	Analyze the pros and cons of alternative manufacturing or construction processes and participate in the selection of the optimum approach
	5. Design	Design is the means by which ideas become reality and which enables useful products and projects to be manufactured and constructed	Contribute to the development of alternatives and prepare design details for complex projects

	6. Engineering Economics	Economic analysis is essential in comparing alternatives	Prepare detailed cost estimates of initial capital and annual operation, maintenance, repair, and replacement costs for a project or component of a project
	7. Engineering Science	Engineering science is the bridge from pure science to engineering	Employ principles and concepts from one or more applicable areas of engineering science to solve engineering problems
	8. Engineering Tools	Engineers must keep abreast of the tools being used and developed in their area of expertise	Identify the advantages and disadvantages of a tool applied within an engineer’s area of specialization
	9. Experiments	Experiments provide insight into cause and effect by demonstrating what outcome occurs when a particular factor is changed	Conduct an experiment and analyze and interpret the results
	10. Problem Recognition and Solving	The essence of engineering is recognizing and solving problems	Analyze existing conditions and develop a complete and accurate problem statement
	11. Quality Control and Quality Assurance	The measure of a project's quality is how well the results conform to all requirements	Apply or review quality control and/or quality assurance procedures on a project component
	12. Risk, Reliability, and Uncertainty	Risk, reliability, and/or uncertainty assessment is essential in engineering practice	Apply concepts of risk, reliability, and/or uncertainty as an integral part of engineering design and decision making

	13. Safety	In manufacturing, safety is an integral component of design to ensure the safety of workers and consumers of products	Identify and apply the safety-related regulatory requirements pertinent to a process, project component, or product
	14. Societal Impact	An understanding of societal context is a critical aspect of most engineering activities	Assess the environmental, economic, and societal impacts of project alternatives and explain the impacts of those alternatives to project stakeholders
	15. Systems Engineering	Systems engineering seeks to make the best use of personnel, material, equipment, and energy	Analyze the pros and cons of alternative design options and assist in the selection of an optimized design alternative based on overall system characteristics and performance
	16. Operations and Maintenance	The safe, reliable, and cost-effective operation and maintenance of engineered systems and works requires engineering supervision	Develop standard operating procedures and methods for the safe and reliable operation and maintenance of engineered systems and works
	17. Sustainability and Environmental Impact	Engineers should focus on sustainable materials, processes, systems, and resource and energy use	Identify information needed to understand and analyze the effects on the environment, economy, and society for a product, process, or system or components of them
	18. Technical Breadth	In order to function as members of multidisciplinary teams, engineers need to have working knowledge of other disciplines	Describe the basic principles of a related science or technology pertinent to a specific area of engineering practice

	19. Technical Depth	As technology advances, technical depth in a given field becomes more important	Choose topics most appropriate for continuing education to increase depth of technical knowledge pertinent to the specific area of engineering practice
Professional Practice	20. Business Aspects of Engineering	Engineers work within a business framework and must recognize the related opportunities and constraints	Describe the basic elements of contracts, costing approaches, and fee structures
	21. Communication	An engineer needs to communicate effectively with technical and nontechnical audiences	Plan, prepare, and deliver an oral presentation with appropriate visual aids, handouts, and/or other support materials
	22. Ethical Responsibility	Ethical values and principles manifest themselves in all engineering practice areas	Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action
	23. Global Knowledge and Awareness	The effectiveness of engineers will increasingly be determined by their understanding of global developments and influences	Discuss the importance of finding and implementing technologies and products from global sources
	24. Leadership	The engineer who is in a leadership mode moves a team or group into new areas	Identify the individuals and groups that could be positively or negatively affected by the change and describe those impacts to each of the groups
	25. Legal Aspects of Engineering	Engineers working on projects must be aware of and comply with applicable local, state, and federal laws and regulations	Describe and interpret applicable codes in design and in construction or manufacturing

26. Lifelong Learning	Lifelong learning is necessary in order to remain current in the midst of changes in knowledge, technology, and tools	Perform a self-evaluation to recognize preferences, strengths, and weaknesses
27. Professional Attitudes	An engineer's attitudes are important components of professionalism	Examine, using actual situations, how attitudes advanced or hindered an engineering project
28. Project Management	Project management is the process by which an engineering organization meets deliverable, schedule, and budget requirements and manages human resources	Formulate documents to be incorporated into a project plan
29. Public Policy and Engineering	Although public policy affects the various types of engineering practice in different ways, all engineers are impacted	Describe how public policy affects engineering practice in an engineering discipline
30. Teamwork	Engineers serve on teams and must function effectively as team members	Identify elements of successful teamwork

Chapter 5

The Next Steps

It is recommended by the NSPE Licensure and Qualifications for Practice Committee that, following adoption, the Engineering Body of Knowledge be distributed widely within the engineering profession for informational purposes and that the LQPC solicit feedback, through the following steps:

1. Prepare and distribute widely a print version of this document. An appropriate distribution list might include state societies of NSPE, other engineering societies, licensing boards, and deans of engineering programs;
2. Provide a free downloadable PDF of this document in a prominent location on the NSPE Web site, accessible to NSPE members and nonmembers alike;
3. Prepare a concise, summary handout of this document for use in presentations;
4. Publish an article in *PE* magazine and prepare a document suitable for distribution by NSPE via social media;
5. Propose and make presentations at key and relevant annual meetings of engineers involved in engineering practice, licensure, and engineering education to introduce and describe the Engineering BOK;
6. Actively solicit, gather, and archive feedback on the Engineering BOK for consideration of concepts to be incorporated in a subsequent edition, if and as appropriate;
7. The NSPE LQPC should review NSPE Position Statement 1752 advocating the inclusion of professional practice topics in engineering education to determine whether any modifications to that advocacy are advisable based on the Engineering BOK; and
8. The NSPE LQPC should review NSPE policies and position statements pertaining to engineering licensure to determine whether NSPE should consider modifications to the requisite professional qualifications for the practice of engineering as a professional engineer based on the Engineering BOK.

Acknowledgements

The following engineering societies provided helpful comments on drafts of this report:

- American Institute of Chemical Engineers (AIChE)
- American Society of Agricultural and Biological Engineers (ASABE) (Sonia Maassel Jacobsen, P.E.; Kevin Keener, Ph.D., P.E.; and Dana Porter, Ph.D., P.E.)
- American Society of Civil Engineers (ASCE) (Richard Anderson, P.E.; Kenneth Fridley, Ph.D., P.E; Blaine Leonard, P.E.; Mark Killgore, P.E.; and Thomas Lenox, Ph.D.)
- Institute of Electrical and Electronic Engineers – USA (IEEE-USA)
- Japan Society of Professional Engineers (JSPE) (Masahiko Tsuchiya, P.E.)

The following individuals, who were not members of the NSPE LQPC, kindly contributed to the initial drafting of some of the capability descriptions appearing in Appendix D:

- Decker B. Hains, Ph.D., P.E., Professor of Military Science, Western Michigan University, Kalamazoo, MI
- Daniel R. Lynch, Ph.D., Professor with the Thayer School of Engineering, Dartmouth College, Hanover, NH

Appendix A

Abbreviations

AAEES	American Academy of Environmental Engineers and Scientists
ABET	Formerly Accreditation Board for Engineering and Technology Inc. (now simply ABET)
ACEC	American Council of Engineering Companies
ANSI	American National Standards Institute
AIChE	American Institute of Chemical Engineers
ASABE	American Society of Agricultural and Biological Engineers
ASCE	American Society of Civil Engineers
ASEE	American Society for Engineering Education
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
AWWA	American Water Works Association

BOK	Body of Knowledge—the necessary depth and breadth of knowledge, skills, and attitudes required of an individual to practice as a professional engineer
EI	Engineer Intern
EJCDC	Engineers Joint Contract Documents Committee
IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
LQPC	Licensure and Qualifications for Practice Committee of NSPE
NAE	National Academy of Engineering
NCEES	National Council of Examiners for Engineering and Surveying
NEC	National Electrical Code
NFPA	National Fire Protection Association
NSPE	National Society of Professional Engineers
PE	Professional Engineer
PEC	Professional Engineers in Construction of NSPE
PEHE	Professional Engineers in Higher Education of NSPE

PEI	Professional Engineers in Industry of NSPE
PEPP	Professional Engineers in Private Practice of NSPE

Appendix B

National Society of Professional Engineers

Licensure and Qualifications for Practice Committee

2012–13

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Arthur E. Schwartz, CAE, JD (Staff Liaison, NSPE LQPC)

Appendix C

Engineering Disciplines

Note: The following list is based explicitly on named engineering programs for which ABET has established accreditation criteria.[5]

Aerospace Engineering

Agricultural Engineering

Biochemical Engineering

Bioengineering

Biomedical Engineering

Biomolecular Engineering

Biological Engineering

Ceramic Engineering

Chemical Engineering

Civil Engineering

Computer Engineering

Construction Engineering

Electrical Engineering

Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Environmental Engineering

General Engineering

Geological Engineering

Industrial Engineering

Manufacturing Engineering

Marine Engineering

Materials Engineering

Metallurgical Engineering

Mechanical Engineering

Mining Engineering

Naval Architecture

Nuclear Engineering

Radiological Engineering

Ocean Engineering

Petroleum Engineering

Software Engineering

Surveying

Systems Engineering

Appendix D

The Body of Knowledge

Necessary for Entry into the Professional Practice of Engineering Expressed as Capabilities

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BASIC OR FOUNDATIONAL CAPABILITIES

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1. Mathematics

Description

Mathematics, in its purest form, may be defined as "the abstract study of topics encompassing quantity, structure, space, change, and other properties."[7] Mathematics uses logic and calculation. Applied mathematics is the use of mathematics to work on practical problems in many disciplines and professions, including engineering.[8] In addition to providing a widely applicable set of tools for engineers, the study and use of mathematics helps engineers develop disciplined thinking.

Branches of mathematics applied in engineering include arithmetic, algebra, geometry, trigonometry, calculus, differential equations, numerical analysis, optimization, probability and statistics, simulation, and matrix theory. Engineers apply mathematics in a wide variety of functions typically carried out in engineering organizations such as planning, design, manufacturing, construction, operations, finance, budgeting, and accounting.

Example Abilities

As examples of mathematics capability, an engineer entering practice at the professional level should be able to:

- Apply an appropriate area of mathematics in the planning or design of a portion of a facility, structure, system, or product;
- Organize and analyze a data set to determine its statistical variability;
- Apply trigonometry, probability and statistics, differential and integral calculus, and multivariate calculus to solve engineering problems; and
- Apply differential equations to characterize time-dependent physical processes.

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2. Natural Sciences

Description

A firm foundation in the natural sciences supports the work of engineers as they apply scientific principles to solve challenging and complex problems. All engineering fields are rooted in one or more of the natural sciences. In a broad context, natural science is separated into physical and biological sciences. Physical sciences include chemistry, calculus-based physics, astronomy, geology, geomorphology, and hydrology. Biological sciences involve living systems and include biology, physiology, microbiology, and ecology.

In addition to the basic scientific literacy in the natural sciences, especially those directly supporting a given engineering field, engineers benefit from a background in natural sciences as applied to the scientific method, problem solving, and inquiry processes that develop critical thinking skills. The natural sciences also foster imagination in the engineering thought process and provide strong analytic skills and the ability to test assumptions. Through understanding of natural sciences, engineers learn how to think systematically and apply concepts of the natural sciences in the identification and solution of engineering problems.

Example Abilities

As examples of natural science capability, an engineer entering practice at the professional level should be able to:

- Use elements from one or more areas of natural science to aid in design;
- Explain key concepts of the scientific method and other inquiry and problem-solving processes;
- Employ the scientific method and/or associated inquiry processes to test basic theories in one or more areas of natural science as they apply to engineering projects;
- Apply critical thinking skills through the application of the scientific method and/or associated inquiry processes in one or more areas of natural science; and
- Use the laws of science to solve engineering problems.

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3. Humanities and Social Sciences

Description

The humanities focus on understanding, in a qualitative manner, various aspects of individuals and society, including, but not limited to, their goals, their social nature, their values, their successes and failures, their aspirations, how all of these are expressed, and, by extension to the engineering profession, how people and the common good are served or adversely affected by technology. Examples of humanities topics that help to develop an understanding of the human condition are literature, history, languages, philosophy, religion, and visual and performing arts.[9]

The social sciences also seek an improved understanding of the human condition. In contrast with the humanities, the social sciences are scientific disciplines in that they, like engineering and the natural sciences, construct theories or hypotheses, observe phenomena, collect data, and perform analysis. That is, the social sciences use a primarily quantitative approach. Some examples of social sciences topics are macroeconomics, communication studies, political science, sociology, anthropology, human geography, and psychology.[10]

The growing importance of the humanities and the social sciences as integral elements of successful engineering is suggested by a vision for the engineering profession as expressed by the National Academy of Engineering in 2004: "We aspire to [have] engineers in 2020 who will remain well grounded in the basics of mathematics and science, and who will expand their vision of design through a solid grounding in the humanities, social sciences, and economics."[2] ABET, the nongovernmental organization that accredits university programs in various disciplines, including engineering, recognizes the engineering importance of understanding the human condition. ABET's accreditation criteria address the need "to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[5]

Engineering is ultimately a people-oriented activity, both in how it is done and in its goal of enhancing the quality of human life. The engineer must appreciate and apply aspects of the humanities and social sciences in order to achieve the critical objective of providing valuable service to, and improving the lives of, people. Simply stated, the humanities examine the "what" of human values, and the social sciences address the "how."

Example Abilities

As examples of humanities and social sciences capability, an engineer entering practice at the professional level should be able to:

- Define the service needs of project stakeholders or product consumers so as to reflect their values and requirements;
- Explain the technical aspects and benefits of an engineering project to nontechnical audiences;
- Evaluate general public input and develop that input into technical possibilities as appropriate;
- Evaluate perspectives from local, state, or national culture or history and related societal trends in the development of a current project;
- Arrange and help facilitate a meeting during which individuals with varied values will attempt to reconcile different desired outcomes of a project;
- Evaluate, for a new technical development, institutional arrangements that will provide effective management of a facility or system, or mitigate public risks;

- Identify, for an emerging technology, its potential contribution to the public good and evaluate mechanisms for its delivery such as private market or public ownership; and
- Compare the technical and nontechnical positive and negative features of alternative courses of action and discuss and evaluate these alternatives with decision-makers and stakeholders.

TECHNICAL CAPABILITIES

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4. Manufacturing/Construction

Description

The quality of life, ranging from meeting most basic needs to enjoying advanced amenities, is impacted by manufactured products, including consumer goods and producer goods. Consumer goods are items purchased by the general public. In contrast, producer goods are items purchased by other companies and used to manufacture consumer or producer goods. Manufacturing may be defined as the process by which materials are converted or assembled into higher value products.[11]

Life quality is also heavily dependent on infrastructure which includes, but is not limited to, water supply and wastewater systems, pipelines for liquid fuels and natural gas, agriculture and food distribution infrastructure, transportation systems (e.g., highways, bridges, tunnels, railroads, airports, and ports), stormwater management and flood control systems, communication systems, power generation and distribution systems, and other facilities, structures, and systems supportive of daily life. The infrastructure is built and maintained by the construction, manufacturing, and utility industries.[11]

Engineers and others involved in manufacturing are challenged by trends such as increased globalization, continuous improvement, increasingly tailored products, and reduced time-to-market. On the construction side, engineers must deal with challenges such as the shortage of specialty trades personnel, the shift to innovative project delivery methods, automated and fast-tracked construction methods, Web-based project management, and lean construction.[11]

Example Abilities

As examples of construction/manufacturing capability, an engineer entering practice at the professional level should be able to:

- Identify and prioritize some technical, environmental, economic, regulatory, and other requirements of a manufacturing or construction project;
- Gather and analyze information to understand something to be manufactured or constructed, or a portion of it, in order to help plan the manufacturing or construction process; and
- Analyze the pros and cons of some alternative manufacturing or construction processes and participate in the selection of the optimum approach.

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5. Design

Description

Design, whether used as a verb to represent a process or interpreted as a noun to refer to the result of the process, is a core capability in engineering. As a process, design may be defined as fulfilling client, owner, or customer needs while also satisfying established regulations and codes and meeting the standard of care. Design is the means by which ideas become reality. The design process—the root of engineering—begins with defining the problem and project requirements and is followed by collecting relevant data and information; logical thinking; applying scientific principles; developing alternatives; considering socioeconomic and environmental effects; assessing risk, reliability, operability, and operational safety; specifying quality assurance provisions; using judgment in all aspects; and formulating a plan of action. The final step in the design process is communicating the results in a manner that enables implementation through manufacturing, construction, or some other means.

Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process, often iterative, in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. The design process incorporates engineering standards and multiple realistic constraints.

While the design process typically relies heavily on proven means and methods, it may include innovative approaches. The goal of design is quality; that is, meeting all requirements such as functional needs and staying within a budget. The ultimate result of the design process—the fruit that grows from the root—is an optimal solution consisting of a structure, facility, system, product, or process. More specifically, design leads to highly varied results such as automobiles, airports, chemical processes, computers and other electronic devices, nuclear power plants, prosthetic devices, skyscrapers, ships, and spacecraft.

Example Abilities

As examples of design capability, an engineer entering practice at the professional level should be able to:

- Identify, or work collaboratively to identify, the pertinent technical, environmental, economic, regulatory, and other project requirements and constraints;
- Gather information needed to fully understand the problem to be solved and to form the basis for the evaluation of alternatives and design;
- Contribute to the development of alternatives and prepare design details for complex projects;
- Analyze the pros and cons of some alternative design options and assist in the selection of an optimized design alternative;
- Analyze the constructability or manufacturing feasibility of a project or product;

- Design a basic facility, structure, system, product, or process to meet well-defined requirements; and
- Apply lessons learned from other design projects.

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6. Engineering Economics

Description

The use of economic analysis is fundamental to the engineering design process and to changes in systems, processes, or operations. In evaluating and comparing design alternatives, engineers need to assess initial capital costs; annual operation, maintenance, and repair costs; and periodic replacement of equipment or other components costs and determine the remaining economic value at the end of the evaluation period. Design alternatives typically have different capital and operating costs, with some alternatives having higher capital costs and lower operation, maintenance, and repair costs, while other alternatives offer lower capital costs but higher operating costs. Engineering economic analysis is used in the design process to compare alternatives on an equivalent (present worth or equivalent annual cost) basis, using assumptions for interest rates. This analysis helps ensure the least costly optimized design taking into account the estimated expenditures required and the time value of money.

Once design alternatives are selected, engineers are typically involved in further defining project economics. This is done by estimating total project costs, incorporating the cost of designing and manufacturing or constructing a solution as well as other implementation costs such as management requirements, bonds and insurances, contingencies for as-yet-undefined project requirements, and financing. An essential element of this process is the identification and economic quantification of the risks associated with the project or product. This entire process is often iterative, wherein cost estimates are refined as projects proceed from planning to design to manufacturing or construction. Engineers often interact with managers and other professionals in providing project economic information and opinions of project costs in financial analysis and financing processes.

On some projects, engineers help evaluate life-cycle costs, taking into account annual loan payments as well as annual operation, maintenance, and other recurring costs in the process of setting rates or prices to ensure that revenues to be received are adequate to offset costs. This also often involves interaction with management, finance, and other professionals.

Example Abilities

As examples of engineering economics capability, an engineer entering practice at the professional level should be able to:

- Prepare detailed cost estimates of initial capital and annual operation, maintenance, repair, and replacement costs for a project or component of a project;

- Calculate the return on investment, present worth and/or annual cost and benefit of a project having initial capital and annual operation, maintenance, repair, and replacement costs using appropriate interest, discount, and projected inflation rates;
- Identify and quantify the economic risks associated with a project or product; and
- Compare design alternatives with varying cost profiles on a present worth or annual cost basis.

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7. Engineering Science

Description

Engineering science is the application of scientific knowledge and processes to solve challenging, complex, practical problems. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. Engineering science topics provide a bridge between mathematics and basic sciences on one hand and engineering practice on the other. Traditional engineering science includes areas such as fluid mechanics, statics and dynamics, electric circuits, solid mechanics, thermodynamics, heat transfer, mass transfer, and properties of materials. Additional areas of engineering science are operations research, information technology, nanotechnology, optics, and energy systems. The various engineering disciplines focus on different subsets of engineering science.

A fundamental understanding of engineering science helps engineers comprehend and apply basic principles to formulate solutions to complex problems. Engineers also use engineering science to break complex problems into simpler parts and to model complex processes and problems. Through the study and application of engineering science, engineers develop and fine-tune their problem solving and critical thinking skills. Additionally, because engineering science is the bridge from science to engineering, the study and application of engineering science—that is, connecting science to problem solving—assists in the development of professional skills that engineers use to interact effectively with nontechnical personnel.

Example Abilities

As examples of engineering science capabilities, an engineer entering practice at the professional level should be able to:

- Define key factual information in one or more applicable areas of engineering science as related to a project or product;
- Use knowledge in one or more areas of engineering science to improve an element of a project or product;
- Employ principles and concepts from one or more applicable areas of engineering science to solve engineering problems; and

- Apply critical thinking skills to a project or product based on knowledge of one or more areas of engineering science.

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8. Engineering Tools

Description

Examples of the many and varied engineering tools engineers use today include: office software; computer-aided design and drafting software; process simulators; modeling for design analysis; freehand drawing; electronic and mechanical measuring and monitoring devices; physical and digital models; decision-making techniques; codes and standards; engineering references; communications software; search engines; social media; materials testing procedures; construction and manufacturing equipment; financial statements; electronic communication devices; marketing models; polls and surveys; and many others.

Engineering tools and their applications will continue to evolve rapidly. Therefore, today's engineers and future engineers must keep abreast of the tools being used and developed in their area of expertise and be alert to the possibility of improving the tools and/or their uses.

Example Abilities

As examples of engineering tools capability, an engineer entering practice at the professional level should be able to:

- Select the tool or tools appropriate to the needs of a project;
- Identify the advantages and disadvantages of a tool applied within an engineer's area of specialization;
- Analyze and interpret the results obtained with an engineering tool;
- Develop and improve an engineering tool or its use;
- Develop knowledge and skills with a new or updated tool or tools, and apply the tool or tools in the solution of an engineering problem; and
- Apply maintenance and calibration for an engineering tool.

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9. Experiments

Description

"An experiment is an orderly procedure carried out with the goal of verifying, refuting, or establishing the validity of a hypothesis. Experiments provide insight into cause and effect by demonstrating what outcome occurs when a particular factor is manipulated. Experiments vary greatly in their goal and scale, but always rely on repeatable procedure and logical analysis of the results."[12] Engineers often design and conduct experiments to guide their analysis and design efforts. Experiments are carried out in various modes including, but not limited to, laboratory or pilot-scale chemical, biological, and physical studies; computer simulations; physical model simulations; and full-scale tests in the field or in a production facility.

An experiment may be conducted early in the engineering analysis and design process to test a theory; at a midpoint to assess options; and/or late in that process to assess the performance of all or a portion of a facility, structure, process, system, or product. The underlying idea is to learn from a model of that which is being contemplated, or a portion of it, before proceeding with the final design and manufacture/construction of the full-scale result. Engineers typically participate in four aspects of experiments. They help design experiments, conduct experiments, analyze experimental results, and synthesize the information gained to decide what appropriate actions need to be taken.

Example Abilities

As examples of experimental capability, an engineer entering practice at the professional level should be able to:

- Identify types of experiments conducted by engineers for a specific application;
- Design an experiment to test a hypothesis, such as the potential effectiveness of a proposed solution to an engineering problem;
- Conduct an experiment and analyze and interpret the results; and
- Develop and recommend a plan of action based, in part, on the experimental results.

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10. Problem Recognition and Solving

Description

The essence of engineering is recognizing, defining, and solving problems. Early in an engineer's career this capability tends to focus on technical challenges. However, with experience and increased awareness, many engineers realize that the disciplined engineering method is a powerful and widely applicable approach that can be used, individually and by teams, to solve a wide range of technical and nontechnical problems. Steps in the engineering method include, but are not limited to, recognizing and defining problems, obtaining background data and information, identifying stakeholders, defining requirements and constraints, selecting tools and techniques, developing and comparing alternative solutions, recommending and communicating a course of action, and guiding implementation.

Besides recognizing and solving problems, engineers must also draw on their problem-solving experience to prevent problems from occurring. Problem prevention is also an important part of engineering. Furthermore, engineers should strive to build on their problem-solving and problem-prevention abilities by developing and implementing creative and innovative ways to move in new directions, thereby advancing the engineering state of the art and contributing to society's health, safety, and welfare.

Example Abilities

As examples of problem recognition and solving capability, an engineer entering practice at the professional level should be able to:

- Analyze existing conditions and develop a complete and accurate problem statement;
- Define requirements and constraints related to solving a problem;
- Identify stakeholders;
- Select and apply tools to develop feasible alternative solutions to an engineering problem;
- Compare options and recommend and justify a course of action; and
- Devise and guide an implementation process.

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11. Quality Control and Quality Assurance

Description

Quality may be defined as "conformance to requirements."[13] While the definition is simple, identifying and then meeting all requirements is challenging. More specifically, "quality in engineering is a measure of how well engineering services meet the client's or customer's needs and conform to governing criteria and current practice standards."[14] In accordance with this definition, quality stands on three legs. The first leg is the wants and/or needs of the client, owner, or customer. Governing criteria form the second leg, a leg that includes local, state, federal, and other requirements as well as design and construction and manufacturing criteria prescribed by the engineer or others. The third leg is the standard of care that may be defined as "the level of competence practitioners in their field customarily expect given the circumstances."[15] While the standard of care sets a high bar, it does not mean the engineer's work is expected to be perfect.

Quality control (QC) is defined by the American Society for Quality as "the observation techniques and activities used to fulfill requirements for quality" and may include accuracy and precision definitions. Quality assurance (QA) pertains to "the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled."[16] In essence, QC refers to those actions that are supposed to be accomplished to achieve quality, such as tests, and QA is proof that they were done, such as certifying that a test occurred. Continuous quality assurance in operations can be an important component of design. For instance, the monitoring of continuously operating processes can include statistical process control which entails detection of statistically significant change and programmed decision-making necessary to return the process to a proper state.

Regardless of the phase of a project (e.g., design, manufacturing, construction, operations), QC and QA are typically the responsibility of different individuals or entities within and/or among organizations working on a project. For example, the QC/QA process may be applied within a manufacturing or engineering firm during the design process. The work product of designers, carried out within the organization's QC requirements (e.g., double-checking calculations) might be reviewed as part of the organization's QA requirements by other designers (e.g., reviewing the design concept, assuring that calculation double-checking occurred, and/or making general or detailed parallel calculations). A similar two-part QC/QA process could be used in construction, manufacturing, and operations.

Example Abilities

As examples of quality control and quality assurance capability, an engineer entering practice at the professional level should be able to:

- Define quality in the context of a project component critical to project success;
- Prepare QC and QA specifications for a project component;
- Apply or review QC and/or QA procedures on a project component; and
- Analyze the impact of QC/QA on project performance.

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12. Risk, Reliability, and Uncertainty

Description

Risk is the possibility of an adverse outcome and is typically expressed as the combination of the consequences of an event, or series of events, and the associated likelihood of occurrence. The probability or frequency of occurrence and the resulting impact of an event are the key factors that must be considered in any risk analysis. Mitigation or management of impacts of natural events of very low probability merits consideration in design in certain circumstances where the resulting impacts would be catastrophic.

Reliability is the capacity of a system or component to perform its required functions under stated conditions for a specified period of time. Uncertainty can be defined as a state of having limited knowledge where it is impossible to exactly describe the existing state or future outcome or outcomes.

The assessment of calculated and implicit risk, reliability, and/or uncertainty is a fundamental component of engineering practice. Engineers are faced with determining how much data are sufficient to define a problem or to characterize existing or future conditions. Factors of safety are assessed analytically in some disciplines and subjectively in all areas of practice. Engineering design that involves known and correct inputs can be straightforward. However, more often than not, the various assumptions that are critical to design can be characterized as ranges of conditions or outcomes and the resulting engineering design needs to function reliably over that entire range.

Example Abilities

As examples of risk, reliability, and uncertainty capability, an engineer entering practice at the professional level should be able to:

- Describe the meaning, importance, and significance of risk, reliability, and uncertainty for the protection of public health, safety, and welfare in the design of a facility, structure, process, system, or product;
- Determine the appropriate type and quantity of data required to identify ranges of existing and future conditions in defining a problem to be resolved through design;
- Identify and assess risk, reliability, and/or uncertainty in the design of an engineered component, system, or process including its impacts on the environment, economy, and society;
- Apply concepts of risk, reliability, and/or uncertainty as an integral part of engineering design and decision making;
- Calculate the probability or frequency of occurrence and resulting impact of risk in the design of an engineered component, system, or process;
- Explain to the public issues relating to risk, reliability, and/or uncertainty in the design of an engineered component, system, or process; and
- Compare the pros and cons of alternative design options and assist in the selection of an optimized design alternative based on risk, reliability, and/or uncertainty analysis.

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13. Safety

Description

Safety of the public and of personnel involved in manufacturing, construction, and operations, and compliance with applicable safety regulations, is an abiding concern across industry sectors. Safety can be broadly described in four categories: product, process, design, and occupational. Product safety is concerned with ensuring that the materials and products are safe (e.g., a toaster), or that all hazards are communicated to the end user (e.g., chemicals). Process safety is concerned with design and operation of a manufacturing facility to protect workers against low frequency, high consequence events. In manufacturing, design safety is focused on the process equipment, piping, and instrumentation to ensure the physical components are adequate to manage the hazards of the process. Occupational safety is concerned with high frequency, low consequence events common in an industrial setting (e.g., fall protection, thermal burns). In the design of certain types of facilities, and in certain situations, matters related to security and/or national security are significant safety-related considerations. Emergency preparedness is also an important safety component of design in terms of equipment, systems, and personnel.

In the design of manufacturing systems, processes, and products, safety is an integral component for design engineers throughout the design process to promote worker safety in manufacturing and to encourage the safe use of products by consumers.

Safety in design is managed in a somewhat different manner in the construction industry during conventional design-bid-build contracting. Structural engineers, as an example, are currently responsible for designing a permanent structure such that it meets the governing building codes. The building codes focus on the safety of those who operate and maintain the facility after it is complete. There is no current requirement, however, for design engineers to design the permanent structure such that it is safe to construct. Designers may voluntarily do this as part of improving the constructability of the designs, but there is no legal, contractual, or other requirement in the U.S. to do so. On the other hand, when designing temporary structures such as formwork, shoring, or scaffolding, engineers have an obligation to consider the safety of those affected by the temporary structure after it is built (i.e., the construction workers). In construction in the so-called built environment (buildings and other facilities and infrastructure), contractors, and not design engineers, are responsible for determining and using safe means and methods of construction and the formulation and enforcement of site safety plans to be adhered to by all parties present on the construction site. Construction safety is generally assigned to the contractor because the contractor typically has expertise in this area and has the contractual authority and responsibility to supervise those who are performing the construction work. In meeting this responsibility, contractors are often assisted by licensed construction or safety engineers.

Engineers need to be aware of a variety of federal regulations pertaining to worker and public safety which vary significantly by engineering discipline, product type, manufacturing industry, or construction activity. The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor sets and enforces extensive prescriptive and performance-based standards to ensure safe and healthful working conditions for workers. Adhering to these standards is a critical element of manufacturing, and in the construction and operations of facilities. The U.S. Environmental Protection Agency (USEPA) and state environmental agencies regulate air and water quality to protect public health and safety. Other pertinent safety regulations include those of: the U.S. Consumer Product Safety Commission, an independent federal agency that regulates over 15,000 consumer products; the U.S. Food and Drug Administration of the Department of Health and Human Services, which focuses on food and drug product safety management on behalf of consumers; the U.S. National Highway Traffic Safety Administration of the Department of Transportation (DOT), which regulates automobiles and highway safety; and the Federal Aviation Administration, also of the U.S. DOT, which regulates air safety. These are examples; there are many others, including applicable state regulations. There are also numerous national codes and standards that directly or indirectly address the safety of systems, processes, and products. Examples of codes and standards that in part address safety include: the National Electrical Code (NEC), the International Building Code (IBC), and the codes and standards of the National Fire Protection Association (NFPA), the American Society of Mechanical Engineers (ASME), the International Society of Automation (ISA), and the American National Standards Institute (ANSI). Safety guidance is also provided to engineers in some areas of engineering practice in the form of Recognized and Generally Accepted Good Engineering Practice (RAGAGEP), a concept defined by OSHA and the USEPA to include the full body of standards, codes, published technical reports, and/or recommended practices that apply to a specific activity.

The regulations and standards pertaining to safety change periodically. International, federal, state, and local requirements vary. It is incumbent on engineers to remain current on these regulations and standards within their specific areas of practice to ensure that products, processes, manufacturing, and construction are safe for workers, users of products, operators of facilities, and the general public.

Example Abilities

As examples of safety capability, an engineer entering practice at the professional level should be able to:

- Evaluate and contrast the safety aspects of design alternatives for a process, project component, or product;
- Identify and apply the safety-related regulatory requirements pertinent to a process, project component, or product; and
- Identify changes in safety-related regulatory requirements in a specific area of engineering practice.

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14. Societal Impact

Description

Engineers design facilities, structures, systems, products, and processes that are intended to generally serve society while typically affecting each individual or group in a unique way. For example, the design of a product for marketing to and use by the public needs to incorporate consideration of its usefulness, usability, competing alternatives, demand, and marketability, all of which pertain to the product's societal impact. Similarly, many projects undertaken on behalf of the public require thorough and transparent public decision-making processes that take into account the effects on different stakeholders. Decision-making should also take into account requirements and public preferences regarding investments, level of service, and potential societal and environmental impacts. Engineers often need to actively participate in that decision-making process to assist in reaching an effective public consensus that can be implemented. This requires that engineers have the ability to effectively communicate with the public and interested stakeholders, and have a basic understanding of those public decision-making processes and the impacts that engineering projects have on society. An understanding of the societal context is a critical component of most engineering activities.

Example Abilities

As examples of societal impact capability, an engineer entering practice at the professional level should be able to:

- Analyze the impacts of a project component on different stakeholders;
- Estimate initial and life-cycle costs of a project and assess the impact of that cost and the benefits on users such as taxpayers or purchasers of a product;
- Assess the environmental, economic, and societal impacts of project alternatives and explain the impacts of those alternatives to project stakeholders; and
- Prepare and deliver a presentation to the public regarding the impacts of a project.

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15. Systems Engineering

Description

Systems engineering focuses on the design, control, and integration of systems. Those systems could have a process orientation, such as production, or a product orientation, such as a computer network. The aim of a systems approach to engineering is to improve the system organization, as well as the delivery, quality, and cost effectiveness of system outputs in order to meet increasing demands. As an example, the design of production systems might include facility location, scheduling, inventory, plant layout, material handling, warehousing, and logistics. The design of product systems might include the selection of components and subsystems and the definition and implementation of hardware and software interfaces between them. Systems engineering applies to all types of industrial, commercial, and government activities. Systems engineers make decisions concerning the best use of people, material, equipment, and energy in achieving an organization's aims.

Example Abilities

As examples of systems engineering capability, an engineer entering practice at the professional level should be able to:

- Identify and gather information needed to understand a multidimensional problem to be solved and to form the basis for the evaluation of alternatives and design;
- Contribute to the development of alternatives in complex projects;
- Analyze the pros and cons of alternative design options and assist in the selection of an optimized design alternative based on overall system characteristics and performance;
- Design a basic facility, structure, system, product, or process to meet well-defined requirements; and
- Define, specify, and/or implement effective interfaces between system components and subsystems to meet system-level requirements.

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16. Operations and Maintenance

Description

Effective operations and maintenance are required for the safe, reliable, and cost-effective operation of simple and basic to complex and critical engineered systems and works. In the case of complex systems, engineers may be directly responsible for supervision of operations and maintenance. In other cases, engineers may be involved in planning or other roles necessary for safe operations and maintenance. Examples of such systems and works include power generation and distribution systems, communication systems, water purification and distribution networks, wastewater collection systems and treatment plants, pipelines for liquid fuels and natural gas, agriculture and food distribution infrastructure, information management systems, and numerous other facilities, structures, and systems that are necessary to maintain and enhance daily life.

The need to manage engineered works and systems should be considered and stressed beginning with planning and design. Engineering management should be continued in their operation throughout their useful life. Anticipated operation and maintenance costs are included in life-cycle analysis in the early design phase. The engineer's role continues after the construction project is completed. Operation and maintenance of infrastructure and facility management include planning, organizing, supervising, coordinating, budgeting, staffing, education and training, scheduling, monitoring, inspection, testing, repair, replacement, and the review of overall performance.

Example Abilities

As examples of operation and maintenance capability, an engineer entering practice at the professional level should be able to:

- Identify, during the planning and design of a system or works, the likely operation and maintenance requirements;
- Develop standard operating procedures and methods for the safe and reliable operation and maintenance of engineered systems and works;
- Develop standards for maintenance that provide the greatest reliability of engineered systems and works given the scarce and limited resources that are available;
- Gather and analyze information to enable the cost-effective allocation of resources that are available for maintenance to provide the highest levels of safety and reliability of engineered systems and works;
- Identify and organize the training necessary to develop and maintain the capabilities for technicians, supervisors, and workers so that the organization has the capacity to effectively operate and maintain engineered systems and works;

- Create and maintain the policies and procedures for the planning, organization, supervision, and management of the maintenance and operation of engineered systems and works; and
- Analyze the pros and cons of alternative operation and maintenance methods to optimize the safety, reliability, efficiency, economy, and sustainability of engineered systems and works.

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17. Sustainability and Environmental Impact

Description

Sustainability in design may be defined as the use of natural resources and cycles in human and industrial systems that do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health, and the environment. Sustainability may also be thought of as a path of continuous improvement, wherein the products and services required by society are delivered with progressively less negative impact upon the earth. This envisions incremental improvement over time wherein sustainability is progressively enhanced. An integral part of sustainable design is an understanding of life-cycle analysis. That analysis can be used to identify processes, components, materials, and systems that are major contributors to resource and energy use and environmental impacts; compare different options within a particular process with the objective of minimizing resource and energy use and adverse environmental impacts; and compare different products or processes that provide the same service.[17]

Avoiding or minimizing and appropriately mitigating adverse environmental impacts is an important component of design. This requires obtaining accurate information regarding current environmental conditions and then considering design alternatives and the varying environmental impacts of those alternatives. Addressing adverse environmental impacts is a regulatory requirement reviewed by regulatory decision-makers in some cases, and in almost all cases, an integral part of the design process.

Engineers will need to be leaders in implementing actions that enhance sustainability and sustainable design. The role of the engineer will most likely focus on sustainable materials, processes, systems, and energy use.

Example Abilities

As examples of sustainability capability, an engineer entering practice at the professional level should be able to:

- Describe the meaning and importance of sustainability in project, process, or system design;
- Apply sustainability in the design of a project, process, or system so as to minimize adverse environmental impacts;

- Identify information needed to understand and analyze the effects on the environment, economy, and society for a product, process, or system or components of them;
- Obtain information on the life-cycle analysis for a product, process, or system, or components of them, to be designed; and
- Analyze the pros and cons of alternative design options and assist in the selection of an optimized design based on the life-cycle analysis.

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18. Technical Breadth

Description

As the need for technical depth or specialization has increased in engineering practice, so too has the need for technical breadth. Engineers increasingly function as members of project teams that include engineers of other specialties, scientists, and nontechnical disciplines such as finance, economics, and law. On many engineering projects, multidisciplinary teams work closely together to accomplish project objectives. Specific examples might include control systems engineers working closely with teams of software engineers and computer scientists on a complex control system, or environmental engineers working closely with hydrogeologists, remote sensing experts, and finance professionals on remediating a hazardous waste site.

In order to function on such multidisciplinary teams, engineers need to have a working knowledge of the engineering, technology, science, and other specialties as practiced by various members of the team. This is gained through basic understanding of science and engineering science and through communication with other diverse professionals. Many complex engineering problems need to be addressed using an interdisciplinary approach. In the future, solving these complex problems will require what might be described as "transdisciplinarity" by all project team members.

Example Abilities

As examples of technical breadth capability, an engineer entering practice at the professional level should be able to:

- Identify fields of science and technology that are related to the practice of engineering in a specific area;
- Describe the basic principles of a related science or technology pertinent to a specific area of engineering practice; and
- Integrate concepts of a related science or technology into design of a project, project component, or product.

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19. Technical Depth

Description

As technological knowledge and complexity advance over time, the need for technical depth in a given field of engineering practice becomes more important. For example, in the past 30 years, the practice of electrical engineering transitioned, for many engineers, from competence in both power distribution and control systems to competence in either power distribution or control systems accompanied by basic understanding of the other. Engineers who once specialized in water and wastewater are transitioning to water or wastewater with a basic understanding of the other.

This trend will continue as engineers focus even more on subsets of their subdisciplines, such as choosing to focus within the water supply field on either treatment or distribution of water. This type of technical specialization is increasingly necessary in order to remain abreast of technological developments on a career-long basis. As engineers specialize, they must also be generally capable and conversant in other aspects of their chosen field because most engineering projects are designed, manufactured, constructed, and operated in a full system context with important interrelationships among project components.

The nature of the technical depth varies considerably by discipline and by the nature of the employment situation of each individual. Many engineering positions will continue to require a broad spectrum of knowledge throughout a given engineering discipline and across other disciplines. The trend, however, is toward increased technical depth and specialization in a given area of practice.

Example Abilities

As examples of technical depth capability, an engineer entering practice at the professional level should be able to:

- Describe advancements in engineering research and technology and science in a narrow area of engineering practice;
- Review research articles pertaining to a project component typically encountered in a specific area of engineering design;
- Choose topics most appropriate for continuing education to increase depth of technical knowledge pertinent to the specific area of engineering practice; and
- Maintain knowledge of current types of systems, equipment, information technology, and specifications that accomplish specific design objectives.

PROFESSIONAL PRACTICE CAPABILITIES

20. Business Aspects of Engineering

Description

Engineers in private and industrial practice work within a business framework, and to succeed they must recognize and work effectively within the constraints imposed by that framework. The business aspects of engineering shape how engineers deliver their services. Corporate structures affect the individual's advancement and exposure to risk. Accounting concepts such as overhead, budgets, margin, profit, investment, depreciation, direct and indirect labor, cost, revenue, utilization, and return on investment drive the engineer's day-to-day work. Contract provisions affect how the engineer's work is rendered and compensated. Pricing and fee structures and the necessity for making a profit affect the performance of their services. As they enter practice, engineers must understand business basics because of the profound effect business has on engineering practice and engineering careers.

Engineers in public practice may not be directly subjected to the same business constraints as those in private and industrial practice, but they work under similar constraints. For example, accounting principles are equally important in the public and private sectors, and engineers in public employment often interface and collaborate with engineers in the private and industrial sectors. Therefore, an understanding of the business aspects of engineering is important for essentially all engineers.

Engineers entering private or public practice should be armed with an understanding of business basics. Such an understanding will help them manage their careers as practicing engineers.

The need for engineers to have capability in the business aspects of engineering varies considerably among job situations. In private practice and in many engineering positions in government, the need for business and public administration capability is significant. In certain engineering roles in large manufacturing or other organizations, career-long exposure to the business aspects of the overall organization may be limited.

Example Abilities

As examples of business capability, an engineer entering practice at the professional level should be able to:

- Distinguish among the various kinds of engineering practice including private, industrial, and public;
- Identify the different types of business entities within which engineers practice including closely-held and publicly-held corporations, partnerships, and sole practitioners, and how they are managed and owned;

- Use the financial metrics applicable to engineering practice such as overhead, profit, direct and indirect labor, cost, revenue, and utilization; and

- Describe the basic elements of contracts, costing approaches, and fee structures.

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21. Communication

Description

The engineer inevitably interacts with technical and nontechnical individuals and groups and does so in a variety of settings. Communication is an integral part of the many and varied functions in engineering, such as asking questions and then listening in order to understand problems; writing reports to summarize findings and recommendations; preparing correspondence; making presentations to upper management, potential clients, and/or customers; describing technical topics to nontechnical audiences; preparing plans and other visuals to explain design details to manufacturers, fabricators, and constructors; and formulating equations to summarize relationships.

Forms of communication within engineering practice include listening, reading, observing, writing, and speaking. The most effective engineers are competent in all communication forms, and in a given situation they are able to use one or more forms to enhance understanding, resolve differences, address challenges, and engender support.

An engineer's or an engineering team's concepts, ideas, discoveries, creations, and opinions will contribute to making things happen only if they are effectively conveyed to others. The most exciting vision, the most thoughtful insight, the most elegant solution, or the most creative design are all for naught unless they are effectively communicated. Therefore, effective communication is necessary to achieve success in engineering.

Example Abilities

As examples of communication capability, an engineer entering practice at the professional level should be able to:

- Read and comprehend written communications;

- Listen and comprehend others' verbal and nonverbal communication;

- Use proper spelling, apply rules of grammar and syntax, and use appropriate citations in written communication;

- Write correspondence that clearly and concisely communicates facts and circumstances related to a project, product, or process;

- Draft a complete report, including tables, figures, and/or other supplemental materials, about a basic engineering topic or project;

- Plan, prepare, and deliver an oral presentation with appropriate visual aids, handouts, and/or other supporting materials; and

- Demonstrate effective communication with both technical or nontechnical individuals and audiences.

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22. Ethical Responsibility

Description

Appreciating and understanding the important role engineers play in the lives and well-being of the public is a critical capability. Engineers must be cognizant of fundamental ethical values and principles such as protection of the public health, safety, and welfare; responsibility to engage in competent practice; issuing statements and reports in an objective, comprehensive, and truthful manner; loyalty; confidentiality; honesty; disclosure to employers or clients; avoidance of conflicts of interest; appropriate use or protection of intellectual property; and other fundamental ethical values and principles.

These values and principles manifest themselves in all professional practice areas, including private practice/consulting, construction, industry, government, and education. All engineering disciplines are affected by these and other ethical considerations, such as implications of technology's influence on society; impact of engineering decision-making on the environment; considerations of risk, safety, and liability; and variations in international ethical norms. The key to meeting ethical responsibility is appreciating and understanding applicable regulatory codes of conduct imposed by state engineering licensing boards, which generally follow guidelines provided in the Model Rules of the National Council of Examiners for Engineering and Surveying. Professional and technical societies also provide codes of ethics.

Example Abilities

As examples of ethical responsibility capability, an engineer entering practice at the professional level should be able to:

- Practice in an ethical manner, with personal and professional integrity;

- Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action;

- Distinguish between a moral, legal, or management issue and an ethical matter;

- Assemble appropriate resources to assist in the resolution of an ethical dilemma;

- Formulate the solution to an ethical dilemma at the lowest management level possible, within the practice or management structure, and with the least amount of disruption as appropriate; and

- Select and take appropriate steps to record or to report to higher-level management or to public authorities in the event that an ethical matter is not adequately resolved in a manner consistent with the public health, safety, and welfare.

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23. Global Knowledge and Awareness

Description

Human beings around the world are now more connected than ever, and that connectivity is increasing at an accelerating pace. We are able to communicate large amounts of information and data almost instantaneously to and from essentially anywhere around the globe. The world's diverse cultures are influencing each other at levels never before experienced, both technically and nontechnically, and this affects how engineers practice.

Technology is advancing all over the world and engineers must keep abreast of the developments. Engineering projects use materials that are manufactured and supplied from multiple locations around the globe, and the technical standards that guide and govern such projects are rapidly becoming more international. Engineering projects are being completed by interdisciplinary teams of professionals who may reside in locations that are thousands of miles apart and separated by different languages, political systems, and cultures.

Knowledge and awareness of global impacts and influences on engineering are essential for engineers who work in different cultural settings so that they achieve optimum solutions to the problems they work to solve; deliver solutions that are appropriate for the culture they serve; find products that improve the projects they complete; and/or identify opportunities to improve the level of engineering service they provide. Those optimum solutions need to fit into both local and national cultural and historical contexts.

Global communication in recent years has been facilitated by the common use of the English language in technical documents and publications. In the future, as some engineers work and interact regularly in multiple cultures in a global context, the ability to speak other languages may be necessary.

Example Abilities

As examples of global knowledge and awareness capability, an engineer entering practice at the professional level should be able to:

- Explain the barriers to global interaction including cultural mores and political and socioeconomic systems;

- Discuss the importance of finding and implementing technologies and products from global sources;

- Identify the processes applicable to promulgating international standards that are related to their specific discipline and practice; and

- Understand the role of appropriate technology and capacity-building in global settings.

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24. Leadership

Description

Engineers serve in the roles of leaders, managers, and producers. These roles are related, but different. The leader decides where a team or group should go, the manager provides ideas and plans about the best way to get there, and the producer gets the team there. Leadership might be viewed as focusing on what to do, managing how to do it, and getting it done. The leader advocates change while the manager implements it. In a simplified sense, the leading, managing, and producing functions can also be represented by three Ds: deciding, directing, and doing.[11]

Leading, which is contrasted here with managing and producing, is essential in engineering and aspects of it are often misunderstood. Leadership is the art and science of influencing others toward accomplishing common goals. Leading is a function that anyone can fulfill regardless of position in the organizational hierarchy.[18] Another misconception is that one must be an extrovert in order to lead; that is, introverts need not apply. This is not true.[19, 20] The third and final misconception is that leaders are born, not made. Birth does not define the leadership capability because the necessary knowledge, skills, and attitudes can be learned.[11, 21]

Example Abilities

As examples of leadership capability, an engineer entering practice at the professional level should be able to:

- Define, explain, and apply leadership principles to organize and direct the efforts of an engineering team;
- Identify the gap between the way things are in some part of their organization and the way they could or should be, and propose a new approach to management;
- Identify, assemble, and organize a team to effect needed change in their organization;
- Identify the individuals and groups that could be positively or negatively affected by the change and describe those impacts to each of the groups; and
- Prepare and implement a plan to accomplish the change.

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25. Legal Aspects of Engineering

Description

Engineers working on projects that potentially impact public health, safety, and welfare must be fully aware of and comply with relevant laws and regulations promulgated and enforced by federal, state, and local governments. The manufacturing of many types of products or the construction of various facilities is subject to compliance with established standards and codes. The applicable laws, regulations, standards, and codes are typically unique to each engineering discipline and area of practice. Engineers in many areas of practice play an important role in the preparation, interpretation, and initial adjudication of contracts. The legal aspects of engineering practice are significant and critical to project success.

Laws and regulations, including those pertaining to environmental protection of the air, water, and land, have been established at federal, state, and sometimes local levels in the U.S. and beyond. The U.S. Occupational Safety and Health Administration (OSHA) establishes important worker safety requirements. Local land use and building regulations prescribe detailed requirements pertinent to development and to building construction. These are examples of a myriad of laws and regulations pertinent to engineering design. Engineers need to thoroughly understand the laws and regulations that pertain to each project.

Examples of codes applicable to engineering design include the fire code of the National Fire Protection Association (NFPA), the National Electrical Code (NEC), the American Society of Mechanical Engineers' (ASME) Codes and Standards, specific OSHA regulations, and the International Building Code (IBC). Applicable regulations require that engineering design within these areas be in full conformance with the applicable codes. Standards, such as those adopted by the American National Standards Institute (ANSI) or the American Water Works Association (AWWA), provide detailed requirements for manufactured products that are specified by engineers for component parts of a project design.

Engineers in many areas of practice prepare contract documents for the manufacture or construction of products, facilities, or structures. This effort may include the preparation of detailed specifications for materials, manufacturing and construction processes, and quality assurance, and interacting with lawyers on the preparation of contract general conditions. In manufacturing and construction, engineers are typically required, in many areas of practice, to fairly and accurately interpret the contract documents with respect to specific project circumstances.

Example Abilities

As examples of legal capability, an engineer entering practice at the professional level should be able to:

- Summarize the rationale for, and detailed requirements of, regulations pertinent to the individual's area of engineering practice;
- Describe and interpret applicable codes in design and in construction or manufacturing;
- Identify applicable standards and properly use those standards in preparing specifications and during manufacturing and construction;
- Prepare and interpret contract documents including coordinating plans, specifications, and construction contract provisions; and

- Recognize the ramifications of engineering decisions relative to professional and/or product liability.

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26. Lifelong Learning

Description

Lifelong learning is essential for engineers who, beginning as students, need to create their futures rather than have others create their futures for them. Lifelong learning is necessary in order to remain current in the midst of a continuing and rapid change in scientific knowledge, technology, and engineering tools critical to engineering practice.

Recognition of the need for lifelong learning starts early in formal engineering education and begins with a rigorous self-evaluation of one's preferences such as theoretical pursuits versus practical applications; relative interests in processes, materials, machines, products, facilities, structures, and systems; and inclinations toward one or more functions such as planning, design, manufacturing, construction, operations, regulation, marketing, management, and finance. Professional development requires recognizing strengths to build on and weaknesses to offset. While any of the preceding may change as engineers advance through education and early practice, they do provide a foundation for moving forward with a philosophy of and plan for lifelong learning. It is important for an engineer to recognize and place significant value on the need for lifelong learning. Specific learning needs will change throughout an engineering career, but the need for lifelong learning will be constant.

The resulting lifelong learning program for each engineer will be tailored to a personal assessment. Besides initial formal education, such as a baccalaureate degree in engineering, an engineer's lifelong learning effort may include more formal education in engineering and other fields; working for a variety of employer types such as industrial, consulting, public, and academic; gaining a variety of engineering project experiences; taking on nontechnical responsibilities; and actively participating in professional and business societies and community activities.

Example Abilities

As examples of lifelong learning capability, an engineer entering practice at the professional level should be able to:

- Perform a self-evaluation to recognize preferences, strengths, and weaknesses;
- Identify means by which engineers can continue to learn throughout their careers;
- Formulate a lifelong learning plan and monitor and update it as needed; and
- Execute initial steps in the lifelong learning plan.

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27. Professional Attitudes

Description

Attitudes are the ways an individual thinks and feels in response to a fact or situation. A person's attitudes indicate how they perceive, interpret, and approach professional work. Individual and collective attitudes affect the success of individuals, the projects they work on, their organizations, and the engineering profession. As indicated by the definition of the Engineering Body of Knowledge, attitudes join knowledge and skills to comprise the three essential elements of a body of knowledge.[22]

Appropriate and effective attitudes depend on each situation. Examples of positive attitudes an engineer should exhibit, depending on the particular conditions, to support effective engineering practice include commitment, confidence, consideration of others, empathy, curiosity, creativity, fairness, high expectations, honesty, integrity, intuition, good judgment, optimism, persistence, respect, self-esteem, sensitivity, thoughtfulness, thoroughness, and tolerance.[22]

While professional attitudes overlap with ethical behavior, as illustrated by fairness, honesty, and integrity, the two are not synonymous. Therefore, the Engineering BOK includes both Ethical Responsibility and Professional Attitudes.

Example Abilities

As examples of professional and positive attitudes capability, an engineer entering practice at the professional level should be able to:

- Recognize professional attitudes supportive of engineering practice;
- Examine, using actual situations, how attitudes advanced or hindered an engineering project;
- Demonstrate professional and positive attitudes in actual challenging engineering situations; and
- Analyze the attitudes of others in order to more effectively work with them.

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28. Project Management

Description

The Project Management Institute (PMI) defines a project as "a temporary endeavor undertaken to create a unique product, service, or result."[23] Examples of projects undertaken by private or public engineering organizations are writing a proposal, preparing a report describing an improvement or analyzing a condition, designing a vehicle, conducting a training program, developing a watershed plan, creating or modifying a process to make a product, manufacturing a product, assembling a capital improvement program, and constructing a structure.

PMI defines project management as "the application of knowledge, skills, tools, and techniques to meet the project requirements."[23] Project management is the process by which an engineering organization delivers quality products and services on time and within budget as expected by internal and external clients and customers. Project management is a challenging, widely applied, and essential engineering function.

Example Abilities

As examples of project management capability, an engineer entering practice at the professional level should be able to:

- Analyze a project and formulate effective strategies within the context of the five processes of initiating, planning, executing, monitoring and controlling, and closing;
- Formulate documents to be incorporated into a project plan;
- Identify discrete work tasks and budgets for a portion of a project;
- Compare the pros and cons of alternative design options;
- Direct the project work of one or more team members; and
- Monitor project schedules and costs using appropriate tools such as Gantt charts, other bar charts, precedence diagrams, critical path methods, and the earned value method.

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29. Public Policy and Engineering

Description

Public policy is a course of action that governs how society functions and is served. As related to engineering, public policy manifests itself in the system of laws, regulations, codes and standards, and funding priorities concerning engineers and their projects as promulgated by a governmental entity. Codes and standards have their root in public policy and are generally referenced in the laws and regulations that are developed to guide and protect the public. Project funding is often a result of public policy and is nearly always affected by public policy.

The work of engineers in private practice, and specifically those who serve publicly-based clients, is directly affected by the policies developed and followed by those they serve. In fact, much of the project work they do is a direct result of public policy. Engineers working in industrial settings may be affected less, but public policies still govern much of their practice. They have to understand and adhere to national, state, and local requirements for their facilities; comply with pollution prevention regulations; and respond to local, state, and regional standards for their products. Engineers in public practice are often the very people who enforce the requirements emanating from public policy and sometimes help to establish public policy.

Although public policy affects the various types of engineering practice at different levels and in different ways, all engineers are affected by it. Therefore, all engineers entering professional practice need to have an understanding of public policy and processes and consequent effects on engineering practice.

Example Abilities

As examples of public policy capability, an engineer entering practice at the professional level should be able to:

- Identify the various types of policy-making bodies including administrative, legislative, private, and quasi-public pertinent to a specific area of practice;
- Explain how codes and standards are set and how public policy affects their development;
- Describe how public policy affects engineering practice in an engineering discipline; and
- Demonstrate the application of public policy techniques by participating as an advisor to a policy-making body or public official.

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30. Teamwork

Description

In an increasingly complex professional and societal context, teamwork is necessary in successful business, government, academic, and volunteer organizations. Examples of teams include: engineers of various disciplines designing an assembly line; a student group working on a project; a team of government personnel working together to prepare a grant application; and an ad hoc professional society committee. Essentially all engineers will have many opportunities to serve on teams, initially as a team member and later as a team leader. As used here, teams include groups that meet and work mostly face-to-face as well as virtual teams.

The three key elements of successful teamwork are[11]:

- **Vision, Goals, and Objectives:** While strong performing teams often share a strong commitment to an ambitious vision, members of successful teams invariably know and understand their goal(s) and objective(s) and demonstrate a strong commitment to achieving them.
- **Diversity:** An optimum mix of players is necessary to cover all of the technical and nontechnical needs of the team. Team members should collectively bring the necessary knowledge, skills, attitudes, connections, and time availability.
- **Trusting, communicative structure:** Trust and open, ongoing, intra-team communication are essential. A team values collaboration and seeks consensus. Commitment to the vision, objective, or goal is the "glue" that holds a team together.

All three elements are needed. An exciting vision without diverse players is a dream that is unlikely to be achieved. A talented team working without a vision, goal, or objective will not be able to focus. A visionary and diverse team that cannot communicate and collaborate will fail to reach consensus.

Example Abilities

As examples of teamwork capability, an engineer entering practice at the professional level should be able to:

- Identify elements of successful teamwork;
- Serve as an effective member of a multidisciplinary team; and
- Organize and provide leadership for a team.

Appendix E

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