NSPE's Pan-Engineering BOK

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Abstract

In 2011, the Licensure and Qualifications for Practice Committee (LQPC) of the National Society of Professional Engineers (NSPE) undertook the challenge of defining, for the first time, an aspirational Engineering Body of Knowledge (EBOK). The EBOK needed to be pan-engineering, that is, broad enough to apply to all engineering disciplines, employment situations, and roles while being specific enough to be useful.

The paper describes the reasons for developing the EBOK, the first edition of which was approved by the NSPE board in October 2013, including: advancing NSPE's stated vision, mission, and values; responding to the challenge presented by the National Academy of Engineering (NAE), and learning from the stimulating BOK initiatives undertaken by various engineering societies. The EBOK is defined as the depth and breadth of knowledge, skills, and attitudes appropriate to enter practice as a professional engineer, that is, licensed and in responsible charge of engineering activities that potentially impact public health, safety, and welfare.

After describing the process used to develop the EBOK, the paper focuses on the essence of the EBOK which is a set of capabilities that elaborate on and operationalize knowledge, skills, and attitudes. A given capability consists of many diverse and specific abilities. The 30 capabilities comprising the recommended EBOK are organized into three categories, namely, Basic or Foundational, Technical, and Professional Practice.

The forward-looking EBOK is intended to serve many and varied stakeholders, each of which is noted, to help them thrive in a rapidly changing world. After discussing the similarities and differences between the EBOK and Civil Engineering BOK (CEBOK), the paper concludes with a summary of the means being used to share the EBOK with stakeholders, stimulate thinking about it, and encourage action.

Keywords – abilities, accreditation, body of knowledge, BOK, capabilities, CEBOK, certification board, Civil Engineering Body of Knowledge, disciplines, EBOK, employer, engineer intern, engineer of the future, Engineering Body of Knowledge, faculty, knowledge-skills-attitudes, licensing board, licensure, profession, professional practice, stakeholders, students

Introduction

The primary purpose of this paper is to present the recently released Engineering Body of Knowledge (EBOK),[1] describe the process used to construct it, and outline what it is intended to accomplish.

Secondary purposes of the paper are to:

- Suggest ways educators might utilize aspects of the EBOK
- Indicate how some of the lessons learned[2] in developing the Civil Engineering Body of Knowledge[3] (CEBOK) were applied in creating the EBOK
- Describe the similarities and differences between the EBOK and the CEBOK

Why Develop a Pan-Engineering Body of Knowledge?

NSPE's decision to develop the EBOK was motivated, as illustrated in Figure 1, by the opportunity to support the Society's vision, mission, and values[4]; by the desire to elaborate on the National Academy of Engineering's (NAE's) vision for engineering in this century[5]; and by the opportunity to build on body of knowledge efforts undertaken by some engineering disciplines.[3,6,7] A discussion of each of these three motivations follows.

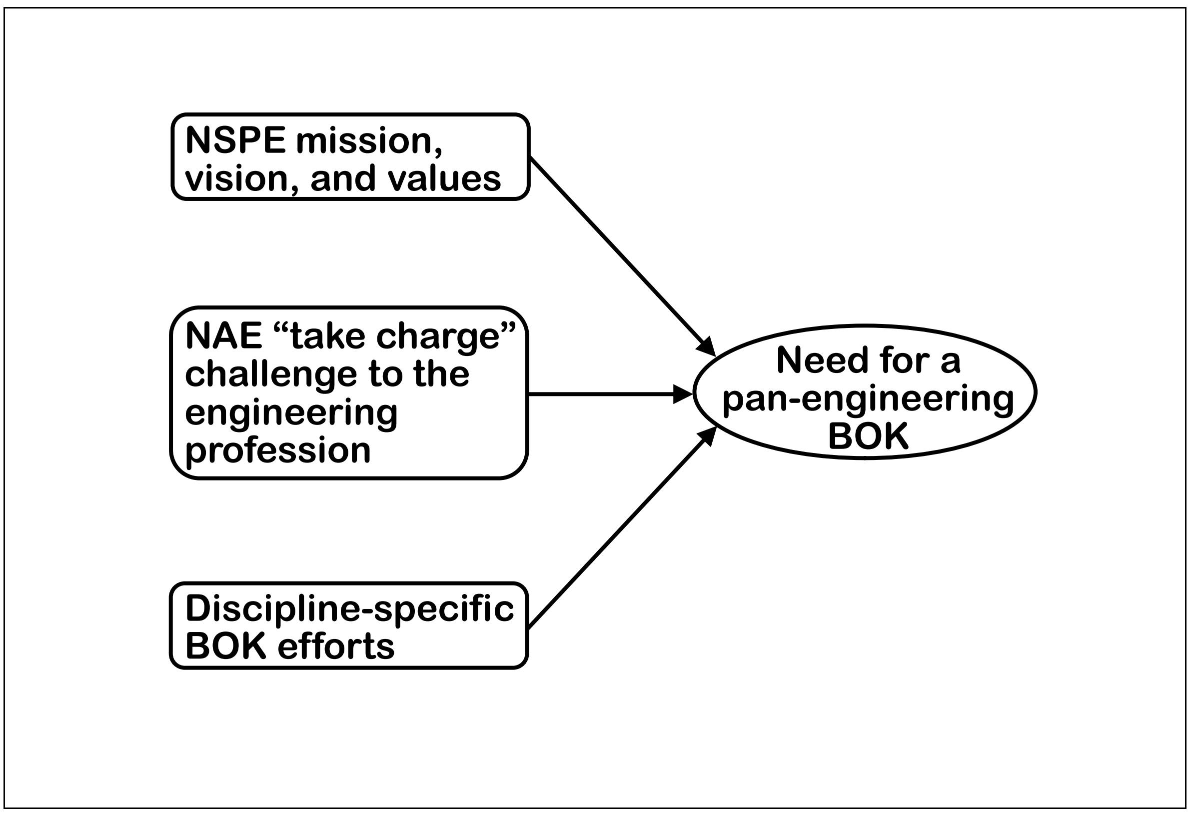

Figure 1. NSPE's development of the EBOK was motivated by three forces.

Support NSPE's Vision, Mission, and Values

The National Society of Professional Engineers (NSPE) EBOK initiative was undertaken in support of the Society's vision, mission, and values. The Vision[4] of the NSPE is to be "the recognized voice and advocate of licensed Professional Engineers." In partnership with the State Societies, NSPE's Mission[4] 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, multi-disciplinary networking, and outreach." NSPE's Vision and Mission are supported by the following eight values[4]:

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
8. Commitment to the future of the licensed Professional Engineer

The forward-looking EBOK, as described in this paper, is linked to and supports all eight values.

In contrast to NSPE's placing the EBOK under the society's vision-mission-values framework, ASCE initiated and completed its BOK prior to having an updated vision. Accordingly, "critics of the [ASCE] Raise the Bar initiative, and especially its foundational BOK element, expressed legitimate concern about the absence of an explicit, over-arching civil engineering vision."[2] Lack of a clear connection between the CEBOK and an over-arching ASCE vision was one factor that motivated ASCE to publish a second edition of its BOK only four years after the first edition. NSPE avoided this weakness by beginning the EBOK effort with explicit reference to and consideration of the NSPE vision-mission-values.

Respond to the National Academy of Engineering's Challenge

The NAE, in its 2004 report[4], *The Engineer of 2020: Visions of Engineering in the New Century*, urges the engineering profession to take the initiative in defining its future. The report implies that if the profession does not create its future, others will. If the profession wants to determine its future, the NAE says that it must: "(1) agree on an exciting vision for the future; (2) transform engineering education to help achieve the vision; (3) build a clear image of the new roles for engineers, including as broad-based technology leaders, in the mind of the public and prospective students who can replenish and improve the talent base of an aging engineering work force; (4) accommodate innovative developments from non-engineering fields; and (5) find ways to focus the energies of the different disciplines of engineering toward common goals." A pan-engineering BOK, that encompasses technical and nontechnical topics like those indentified by NAE, will help the engineering profession create its future for the benefit of society.

Build on Discipline-Specific Body of Knowledge Efforts

Over the past decade, various engineering disciplines have undertaken BOK initiatives and published formal comprehensive bodies of knowledge. Examples are the American Academy of Environmental Engineers[6] (AAEE, now the American Academy of Environmental Engineers and Scientists, AAEES) and the American Society of Civil Engineers[3] (ASCE). Additional examples of societies and other entities that have produced various types of engineering or engineering-related BOKs are summarized in Appendix A. All of these efforts, which represent a wide array of approaches and states of completion, have raised awareness of BOKs and have provided lessons in how to develop and implement them.

Numerous volunteers worked long and hard to develop the NSPE mission-vision-values, produce the NAE report, and initiate BOK efforts in various engineering disciplines. The NSPE EBOK effort benefitted from those earlier efforts. This reflects a lesson learned as a result of ASCE's development of the CEBOK. That lesson was to stand respectfully and thankfully on the shoulders of others.[2]

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 EBOK, as used in this paper, 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
- 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.

Charge Undertaken and Process Used

Charge

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

- Review the NAE report *The Engineer of 2020*[5] and other BOK documents[3,6,7] and determine which elements of these reports apply to all engineering disciplines;
- Prepare an outline of an EBOK common to all engineering disciplines, in the form of broad topics, 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 EBOK and schedule its preparation for, at minimum, a two-year 2012-2013 process.

As indicated by the previously discussed reasons to develop the EBOK, and by the specific charge, the EBOK project was, from the outset, to be about the future, not the present. This aspirational initiative is about tomorrow’s engineering practitioners, not necessarily about today’s. The EBOK is future-oriented in that, while current engineering practice may require many of the EBOK capabilities and some engineers exhibit those capabilities, many more engineers will need to acquire more capabilities or be more adept at those they already have. The EBOK envisions the capabilities of tomorrow’s practicing professional engineers and is intended to include all engineering disciplines practiced in the U.S.

Process Used

The LQPC EBOK Subcommittee developed a draft outline which was approved by the LQPC in March 2012 for review within NSPE. The outline included “Guiding Principles That Will Shape the Future of Engineering” and “Key Attributes of the Professional Engineer” the final versions of which are included as Appendices B and C in this paper. The guiding principles and the key attributes are included here to provide some insight into the thought process that ultimately led to the EBOK. The outline also included an initial list of what would become capabilities, as described later in this paper.

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 website were incorporated into the outline.

Members of the EBOK Subcommittee prepared and presented a webinar[8] about the project in June 2012 and input from it was reflected in the EBOK outline. Individuals and organizations, within and outside of NSPE, were invited to share input. Engineering societies were invited to comment and contributions were received from IEEE-USA, AIChE, ASCE, and the American Society of Agricultural and Biological Engineers (ASABE) and incorporated into the working outline. The American Council of Engineering Companies (ACEC), ASME, the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), and AAEES were also invited, but did not provide comments prior to the October 2013 completion of *Engineering Body of Knowledge*.

However, ASME offered comments after publication. NSPE hopes that other societies, whether or not they have already commented, will do so in response to their study of the EBOK and thoughts about its possible implications for them.

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. That input was incorporated in a final draft for review and approval by LQPC and the NSPE Board of Directors.

The first edition was approved by the NSPE LQPC at its meeting on July 21, 2013 and by the NSPE Board of Directors at its meeting on October 12, 2013. NSPE immediately announced the availability of *Engineering Body of Knowledge* as a free pdf file at http://www.nspe.org/sites/default/files/resources/nspe-body-of-knowledge.pdf

Like the process used by ASCE to develop its BOK,[2,3,7] NSPE tried to function transparently and inclusively as demonstrated by the preceding description of NSPE's process. The EBOK Subcommittee repeatedly sought input from within and outside of NSPE, freely shared evolving draft materials, responded to input received, and invited supporters and critics to offer specific suggestions in writing. However, in keeping with the expression "while we can lead a horse to water, we cannot make it drink," NSPE was unable to generate input from some key engineering organizations and would have welcomed negative input over none at all. The EBOK Subcommittee will continue to work in a transparent and inclusive manner with the hope of engaging and hearing and learning from an expanding group of EBOK stakeholders. Why? Partly because a second edition of *Engineering Body of Knowledge* is possible and would benefit from a wide variety of inputs.

A Living Document

Preparing the EBOK was challenging partly because this was the first time that the U.S. engineering profession attempted to articulate its BOK. The EBOK needed to be broad enough to apply to all engineering disciplines, as well as all employment situations and engineering roles within those disciplines, while being specific enough to be useful to various stakeholders. Accordingly, *Engineering Body of Knowledge* is a living document. Comments are invited and should be forwarded to the NSPE LQPC, through NSPE General Counsel Arthur Schwartz at aschwartz@nspe.org. As already noted, depending on input received, a second edition might be considered.

The current refined and effective CEBOK owes its success partly to having gone through a first edition[7] – second edition[3] process. A concept and document as unique and potentially influential as the EBOK is likely, once it is widely disseminated, to generate a wide range of reviews, including positive and negative comments. That input, drawing on the ASCE experience, could be the basis for an improved second edition.

Definition of Entry into Professional Practice

As explained early in this paper, the EBOK is defined as the depth and breadth of knowledge, skills, and attitudes appropriate to enter practice as a professional engineer, that is, licensed and in responsible charge of engineering activities that potentially impact public health, safety, and welfare.

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. According to the NCEES Model Law[9], responsible charge means "…direct control and personal supervision of engineering work..." NSPE[10] defines responsible charge as "that degree of control an engineer is required to exercise over engineering decisions made personally or by others over which the engineer provides supervisory direction and control authority."

Capabilities and Abilities

Capabilities

In the interest of specificity, EBOK knowledge, skills, and attitudes are referred to as capabilities, that is, the capabilities needed to enter practice as a professional engineer, that is, licensed, in responsible charge of engineering activities that potentially impact public health, safety, and welfare. Each capability defines what an individual is expected to know and be able to do by the time of entry into professional practice in a responsible role.

Each capability is usually acquired through a combination of engineering education and experience. NSPE does 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 engineering disciplines and employment circumstances. Stated differently, the EBOK defines the "what," not the "how."

Note that "capabilities," as used by NSPE in the EBOK, is similar to "outcomes," as used by ASCE in its BOK. Although "outcomes" was originally considered by NSPE, it was rejected because some participants argued that it could be confused with the engineering program outcomes established by ABET. This reflects another lesson learned during the ASCE CEBOK experience, mainly, the unexpected negative reaction caused by some well-intentioned words and expressions.[2] For example, ASCE eventually eliminated "First Professional Degree" and refined use of "master's degree" both of which initially caused negative reactions.

Abilities

A given capability typically consists of many diverse and specific abilities. The abilities are presented in the EBOK as examples; and are just that -- examples. The specific abilities required in each engineering position and in each discipline will vary significantly.

The statement of each ability begins with an active verb to help clarify the intent. Some ability statements include additional active verbs. Consider, for example, the Engineering Tools capability. An example of a supporting ability is "**Identify** the advantages and disadvantages of a tool applied within an engineer's area of specialization." Or using the Communication capability, an example supporting ability is "**Plan, prepare,** and **deliver** an oral presentation with appropriate visual aids, handouts, and/or other support materials."

Overview of the 30 Capabilities

The names of the 30 capabilities in the EBOK are listed in Table 1 where they are organized for clarity in three categories; Basic or Foundational, Technical, and Professional Practice. While the full EBOK is intended to apply across the engineering profession, each engineering discipline and employment situation combination is likely to focus on a relevant subset of the capabilities. More specifically, Table 1 lists the name of each capability, briefly notes its relevance, and gives an example of a supporting ability.

Table 1. Summary of capabilities within the EBOK.

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 are 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 team, 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 projects 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

The capability names in Table 1 are just that, that is, they are names and they do not describe the capabilities. Therefore, in order to further explain the format and content of each of the 30 capabilities, some representative capability descriptions are included as appendices to this paper. Refer to Appendix D for an example of a Basic or Foundational Capability, namely Capability 2, Natural Sciences. As with all of the capabilities, this one consists of two parts. The first is a description of the capability. The second part lists examples of the kinds of natural science abilities an engineer entering practice at the professional level should be able to do.

Continuing with capability examples, see Appendix E for an example of a Technical Capability which is Capability 5, Design, and then Appendix F for an example of a Professional Practice Capability that being 20, Business Aspects of Engineering.

Uses of the Engineering Body of Knowledge

The EBOK 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. The EBOK 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 EBOK to various members of and stakeholders in the engineering community. As illustrated in Figure 2, many engineers and engineering stakeholders can draw on and benefit from the EBOK.

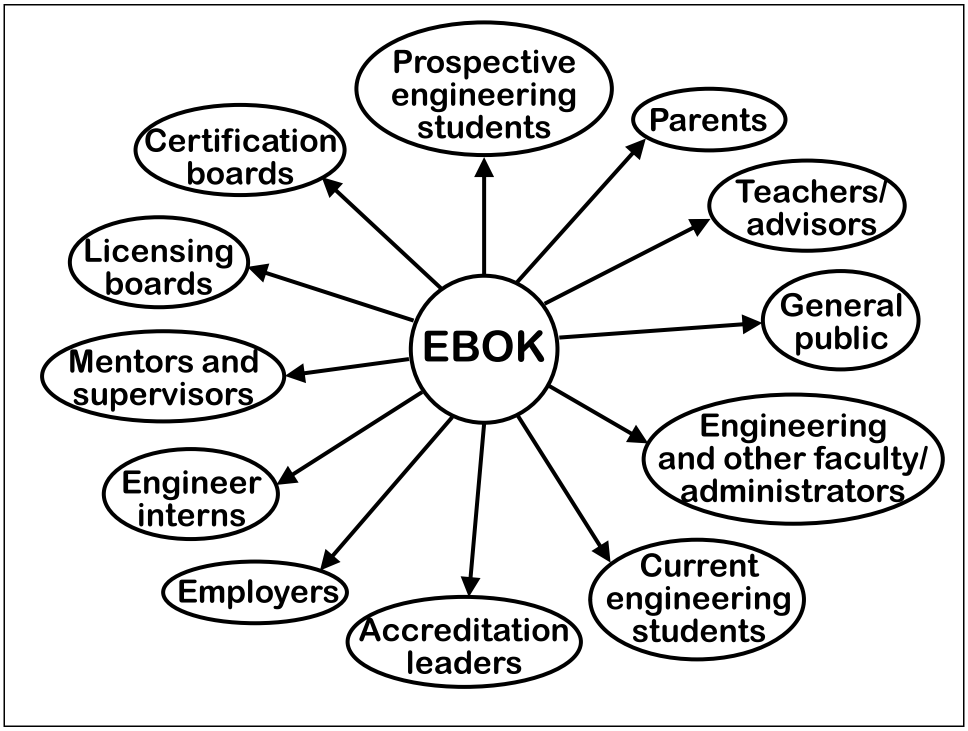

Figure 2. Members of and stakeholders in the engineering community can draw on and benefit from the EBOK.

With an eye to the future, the Engineering BOK:

1. Offers **prospective engineering students,** their **parents,** their **teachers/ advisors**, and the **general public**, a glimpse of the importance of engineering (e.g., guiding principles in Appendix B); indicates the breadth of knowledge and skills required to practice engineering (e.g., key attributes in Appendix C and the capabilities); and suggests the breadth of opportunities offered by an engineering career (e.g., sum of the preceding).

Engineering faculty who host or otherwise assist with student recruitment may find the guiding principles and key attributes helpful in explaining the future of the engineering profession and describing the profile of a successful engineering student and practitioner. The breadth and depth of the principles and attributes could help to dispel inaccurate stereotypical thinking.

2. Assists **engineering and other faculty** in designing curricula, creating and improving courses, arranging co-curricular activities, and teaching and counseling students.

In planning the next offering of one of their courses, a professor might review the 30 capabilities and find that one or more could be integrated into the course in such a way so as to reinforce the course and expand student knowledge and skill. For example, consider Capability 21, Communication, for which one example ability is "Plan, prepare, and deliver an oral presentation with appropriate visual aids, handouts, and/or support materials." On reading and thinking about this, a professor might, regardless of the course he or she is teaching, decide to experiment with having each student present one short presentation during the course. This could enable each student to learn more about a course topic, share it with others, and obtain a useful speaking experience.

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

In that spirit, an engineering faculty member might ask students to download *Engineering Body of Knowledge* and compare its content to their completed and planned coursework and co- and extra-curricular activities. Students might benefit by seeing the engineering profession's knowledge-skills-attitude umbrella under which they are studying engineering.

4. Gives **accreditation leaders** guidance for developing appropriate education criteria.

For example, the EBOK may be useful to ABET/EAC in its discussions of Criterion 3[11] which describe the minimum knowledge and skills that engineers in all disciplines are expected to attain through baccalaureate education.

5. Informs **employers** what they can expect in terms of basic knowledge, skills, and attitudes possessed by engineering graduates and suggests to **employers** their potential role, in partnership with individual entry engineers, in helping them attain the levels of achievement needed to enter the practice of engineering at the professional level.

6. Provides **Engineer Interns** with a comprehensive list of capabilities to assist them in evaluating the existing and desired breadth and depth of their engineering experience.

7. Offers 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.

8. 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.

9. Encourages specialty **certification boards** to build on the EBOK in defining their desired mastery level of achievement.

The Engineering and Civil Engineering BOKs: Similarities and Differences

Comparing the EBOK and the CEBOK provides more insight into each. Consider some ways in which the two BOKs are similar and different.

Both are **aspirational,** that is, they describe a knowledge-skills-attitudes level not widely needed and/or achieved now. These BOKs focus on tomorrow's engineering practitioners, not today's. While current engineering practice may require many of the EBOK/CEBOK capabilities/outcomes and some engineers exhibit them, more engineers will need to acquire more capabilities/outcomes or be more adept at those they already have. These and other BOKs are meant to be the "tide" that lifts all "boats."

The two BOKs are similar in that they define the necessary breadth and depth of knowledge-skills-attitudes required of an individual to **enter practice as a professional engineer,** that is, at licensure. The EBOK explicitly adds "in responsible charge of engineering activities that potentially impact public health, safety, and welfare," a condition that is implicit in the CEBOK.

The BOKs differ somewhat in that the EBOK uses capabilities to elaborate on the desired knowledge-skills-attitudes and the CEBOK uses outcomes. The two systems are similar in that each organizes the capabilities/outcomes into **three essentially identical categories,** namely, Basic/Foundational, Technical, and Professional Practice.

The CEBOK's 24 outcomes generally map into the EBOK's 30 capabilities. However, the EBOK has six extra capabilities mainly because it is intended to apply to all engineering disciplines. The **six additional capabilities,** that is, capabilities not explicitly corresponding to CEBOK outcomes, are: Manufacturing/Construction, Engineering Economics, Quality Control and Quality Assurance, Safety, Systems Engineering, and Operations and Maintenance.

The two BOKs differ markedly in the way they address the role of education and experience in preparing an aspiring candidate to enter practice as a professional engineer. The CEBOK explicitly assigns levels of achievement for each of the 24 outcomes to the bachelor's degree, master's degree or equivalent, or prelicensure experience. In contrast, the EBOK is intentionally silent on how formal education and experience might be used to fulfill the 30 capabilities for entry into professional practice. That is, the EBOK defines the "what," not the "how." This major difference reflects the wide variety of education-experience mixes that are available with the choice of a particular combination being at the pleasure of each discipline.

The Next Steps

Broadly speaking, NSPE's focus is now on widely sharing the *Engineering Body of Knowledge* with those engineers and engineering stakeholders illustrated in Figure 2, and therefore, to stimulate future-oriented thinking. The hope is that such thinking will motivate recipients of the report to contemplate its content, see relevance, and begin to implement changes within their areas of responsibility and influence. NSPE welcomes opportunities to speak about and/or discuss the EBOK.

More specifically, as of late 2014, NSPE began a proactive, systematic outreach effort both within and outside of the Society. Various means of communication were and are being used including email, e-newsletters, blogs, Twitter, Face Book, conference presentations, and briefings for committees and task forces. Refer to Appendix G for details of the outreach effort.

Summary of Key Ideas and Information Presented in this Paper

1. NSPE undertook the challenge of defining, for the first time, an aspirational, pan-engineering BOK and did so to advance NSPE's stated vision, mission, and values; respond to the NAE challenge; and build on the stimulating BOK initiatives undertaken by various engineering societies.

2. The EBOK is 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.

3. In the interest of specificity, EBOK knowledge, skills, and attitudes are referred to as capabilities and each capability consists of many diverse and specific abilities. The heart of the EBOK is 30 capabilities organized for clarity in three categories; Basic or Foundational, Technical, and Professional Practice.

4. In developing the EBOK, NSPE tried to function transparently and inclusively, and will continue to do so, with the hope of engaging an expanding group of EBOK stakeholders in anticipation of learning more and possibly using that knowledge to produce a second edition.

5. The EBOK is designed to be useful, in a variety of ways, to various stakeholders, that is, members of the engineering profession and those with whom they interact; it is not an abstract concept. The EBOK is a foundation on which professionals prepare for and build careers and from which they communicate the essence of their profession to others.

6. NSPE's focus in now on widely sharing the *Engineering Body of Knowledge* with those engineers and engineering stakeholders to stimulate future-oriented thinking. The hope is that such thinking will motivate recipients of the report to do two things:

- First, contemplate its content, see relevance, and begin to implement changes within their areas of responsibility and influence.
- Second, suggest improvements to the report that will be considered if NSPE prepares a second edition.

NSPE welcomes opportunities to speak about and/or discuss the EBOK. Accordingly, as of late 2014, NSPE began a proactive, systematic outreach effort both within and outside of the Society.

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Appendix A: Miscellaneous BOKs and BOK Initiatives

The purpose of this appendix is to suggest that a BOK movement is underway within some engineering disciplines, in addition to the BOKs cited in the section of this paper titled "Build on Discipline-Specific Body of Knowledge Efforts." This appendix's purpose is accomplished by citing and very briefly summarizing some additional engineering BOK efforts. The incidents are suggestive of what is happening, however, they are not all-inclusive.

- The American Society of Mechanical Engineers (ASME) formed a Body of Knowledge Task Force in 2003 and the "ME Body of Knowledge Blog" functioned during 2008 and 2009. See: ASME Council on Education, "A Vision of the Future of Mechanical Engineering, November 2004. In 2008, ASME published *2028 Vision for Mechanical Engineering.* It does not refer to the earlier MEBOK efforts.

- ASME published, in 2010, *Guide to Engineering Management Body of Knowledge.* The EM BOK consists of eight domains of engineering management knowledge broken down into 46 knowledge areas and 210 sub-knowledge areas. The eight domains are: 1) Market Research, Assessment, and Forecasting; 2) Strategic Planning and Change Management; 3) Product, Service, and Process Development; 4) Engineering Projects and Process Management; 5) Financial Resource Management; 6) Marketing, Sales, and Communications Management; 7) Leadership and Organizational Management; and 8) Professional Responsibility, Ethics, and Legal Issues.

- The Society of Manufacturing Engineers (SME) published, in 2010, *Certified Manufacturing Technologist and Certified Manufacturing Engineer Body of Knowledge.* This BOK is presented in the form of these categories: 1) Mathematics, Applied and Engineering Sciences, and Materials; 2) Product/Process Design and Development; 3) Manufacturing Process Applications and Operation; 4) Production System and Equipment Design/Development; 5) Automated Systems and Control; 6) Quality and Continuous Improvement; 7) Manufacturing Management; and 8) Personal Effectiveness.

- Stevens Institute of Technology published, in 2013, *The Guide to the Systems Engineering Body of Knowledge* edited by A. Pyster and D. Olwel. The SEBOK is partitioned into these seven parts: 1) Introduction, 2) Systems, 3) Systems Engineering and Management, 4) Applications of Systems Engineering, 5) Enabling Systems Engineering, 6) Related Disciplines, and 7) System Engineering Implementation Examples.

- The IEEE Computer Society published, in 2014, *Guide to the Software Engineering Body of Knowledge.* The SWEBOK is comprised of these 15 knowledge areas: 1) Software Requirements, 2) Software Design, 3) Software Construction, 4) Software Testing, 5) Software Maintenance, 6) Software Configuration Management, 7) Software Engineering Management, 8) Software Engineering Process, 9) Software Engineering Models and Methods, 10) Software Quality, 11) Software Engineering Professional Practice, 12) Software Engineering Economics, 13) Computing Foundations, 14) Mathematical Foundations, and 15) Engineering Foundations.

- The Wiley-IEEE Press published, in 2014, *A Guide to the Wireless Engineering Body of Knowledge - 2nd Edition* edited by Andrzej Jajszczyk. The WEBOK is structured around these major topics: 1) Wireless Access Technologies, 2) Network and Service Architecture, 3) Network Management and Security, 4) Radio Engineering and Antennas, 5) Facilities Infrastructure, 6) Agreements, Standards, Policies, and Regulations, and 7) Fundamental Knowledge.

- The American Society for Quality (ASQ) published (date not known, but recent) *Certified Quality Engineer (CQE) Body of Knowledge*. It is designed to help a candidate for Certified Quality Engineer prepare for the exam. The major categories are: 1) Management and Leadership, 2) The Quality System, 3) Product and Process Design, 4) Product and Process Control, 5) Continuous Improvement, and 6) Quantitative Methods and Tools.

Appendix B: 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*[5]. 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 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 non-engineers 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.

Appendix C: 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
- Dedicated to lifelong learning

Appendix D: Example of a Basic or Foundational Capability – 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.

Appendix E: Example of a Technical Capability – 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 satisfying 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.

Appendix F: Example of a Professional Practice Capability – 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.

Appendix G: Engineering Body of Knowledge Presentations, Articles, and Other Outreach

As of late March 2014, the following sharing steps had been taken or were planned by NSPE:

1. Offered *Engineering Body of Knowledge* as a free pdf at http://www.nspe.org/sites/default/files/resources/nspe-body-of-knowledge.pdf

2. Announced the completion and availability of the report within NSPE. More specifically, the *Engineering Body of Knowledge* was referred to and/or mentioned in/by: NSPE Homepage, NSPE Leader Brief, NSPE Twitter, NSPE Face book, NSPE Linked In, NSPE Update, NSPE Leadership Talking Points, NSPE Board of Directors Update, NSPE's Daily Designs, NSPE Licensure Blog, PEC Reporter, PEG e-News, PEI e-News, PEPP Talks, NSPE Legislative and Government Affairs Committee, NSPE Licensure and Qualifications for Practice Committee, and the NSPE House of Delegates.

3. Provided the report, outside of NSPE, to the American Association of Engineering Societies (AAES) Lifelong Learning Task Force, the NCESS Education Committee, and the 2013 Annual ABET/ASCE/NCEES/ASEE/NSPE Senior Leadership Meeting.

4. Sent approximately 70 technical society executive directors and/or presidents an e-mail about *Engineering Body of Knowledge* and its access as a free pdf. They were asked to widely share the information/report and to provide input to NSPE.

5. Arranged and/or completed presentations at the following events:

    - ABET Symposium, April 2014, Pittsburg, PA
    - Indiana Society of Professional Engineers Annual Conference, June 2014, Indianapolis, IN
    - New Mexico Society of Professional Engineers Annual Meeting, June 2014, Albuquerque, NM
    - ASEE Annual Conference, June 2014, Indianapolis, IN
    - NCESS Annual Meeting, August 2014, Seattle, WA
    - Florida Engineering Society Annual Conference, August 2014, Marco Island, FL.

6. Explored the possibility of making presentations at the following conferences:

    - NSPE Annual Meeting, July 2014, Washington, DC
    - World Federation of Engineering Organizations (WFEO) World Engineering Conference and Convention, November 2015, Kyoto, Japan

7. Published or helped to arrange the following:

- “What Makes a PE?,” *PE,* January-February 2014
- “What Engineers Should Know and When They Should Know It,” *PE,* January-February 2014
- “The Engineering BOK,” *Licensure Exchange,* NCEES, April 2014
- “NSPE’s Pan-Engineering BOK,” Proceedings of the ASEE Annual Conference, June 2012

8. Discussing ways to communicate more directly with each of the many and varied engineers and engineering stakeholders and determining the most effective means to inform them about the EBOK and its possible value to them.

9. Coordinating with the ASCE Continuing Education Blue Sky Task Force charged to examine the program’s “challenges and opportunities and articulate an aspirational vision for the future of ASCE’s Continuing Education Program.” This group will consider the EBOK, and other BOKs, when planning the direction of future continuing education programs.