ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE: SUMMARY REPORT

AAEE Environmental Engineering Body of Knowledge Working Group[1]

ABSTRACT

To better define the knowledge and skills required for the practice of environmental engineering, the American Academy of Environmental Engineers (AAEE) sponsored a Body of Knowledge Working Group (BOKWG) to define the knowledge, skills and abilities needed to practice environmental engineering at the professional level. The Working Group adopted an outcomes based approach and identified 18 outcomes. Bloom's Taxonomy enhanced by the Daggett Rigor/Relevance Framework™ was used to identify the cognitive rigor and applicative relevance level expected for each outcome at the baccalaureate, masters (or equivalent) and after 4 or more years of professional experience. The Working Group Draft Report summarized here is undergoing a peer review by educators and practitioners. Comments are welcome and should be directed to Dr. Debra Reinhart at reinhart@mail.ucf.edu.

I. INTRODUCTION

In 2005 the American Academy of Environmental Engineers (AAEE) celebrated its 50th anniversary. The practice of Environmental engineering certainly predates AAEE; however, it had traditionally been viewed as "sanitary engineering," a subset of civil engineering. In the latter half of the twentieth century, particularly in the 1980's and 1990's, environmental engineering evolved into a stand-alone engineering discipline.

An environmental engineer must have a broad array of technical and non-technical knowledge, abilities, skills, and attitudes. Although the knowledge and skills required of environmental engineers were the focus of several Environmental Engineering Education Conferences, (AAEE and AEESP 1986, 1991 and 1996) there has not been a comprehensive effort to identify and describe them in terms of outcomes. In 2005, the American Academy of Environmental Engineers established a Body of Knowledge Working Group (BOKWG) charged with: "defining the BOK needed to enter the practice of environmental engineering at the professional level (licensure) in the 21st century taking into account other issues, including, but not limited to, the impact on AAEE, on the profession, on environmental engineering academic programs (undergraduate and graduate), and on accreditation of environmental engineering programs at the basic and advanced levels."

The Environmental Engineering BOK Working Group Draft Report (AAEE, 2008) summarized here describes the knowledge and core competencies integral to the understanding and practice of environmental engineering. Acquiring the EnvE BOK could lead to environmental engineering licensure and specialty certification or to related careers that do not require licensure. The EnvE BOK builds on outcomes applicable to all engineering specialties and adds outcomes specific and unique to environmental engineering. The outcomes identified will help educators to design curricula that provide the basis to gain the competencies needed for professional practice and will assist licensing boards to determine the expertise required for licensure.

In 2008, the American Society of Civil Engineers published the second edition of the Civil Engineering Body of Knowledge for the 21st Century (ASCE, 2008). The Environmental Engineering Body of Knowledge has many things in common with the Civil Engineering BOK, and the AAEE BOK Working Group acknowledges the help received from ASCE, particularly the contributions of ASCE Honorary member Stu Walesh.

II. BACKGROUND

A. Definition of Environmental Engineering

Various definitions of environmental engineering have appeared in the literature, and these have been summarized by Baillod et al. (1991). The following definition adapted from Gilbertson (1973) is used herein:

Environmental engineering is defined as that branch of engineering concerned with the application of scientific and engineering principles for:

- Protection of human populations from the effects of adverse environmental factors;
- Protection of environments, both local and global from the potentially deleterious effects of natural and human activities; and
- Improvement of environmental quality.

Environmental engineers practice in both the public and private sectors. Typical duties of environmental engineers are:

- Evaluation of environmental quality, especially when it involves a risk to public health, and/or when degradation has or may occur as a result of anthropogenic activities – e.g., quality of water, air, soils;
- Development of strategies and methods to prevent environmental degradation or public health risk;
- Development of regulations and requirements for performance of

pollution prevention or environmental quality improvement, protection, or remediation projects:

- Design of facilities or programs for pollution prevention or environmental quality improvement, protection, or remediation;
- Evaluation of the results of pollution prevention or environmental quality improvement, protection, or remediation; and
- Assessment of the economics and efficiency of processes and procedures used in pollution prevention or environmental quality improvement, protection, or remediation.

B. Education for Environmental Engineering

Most practicing environmental engineers have post-baccalaureate education, frequently earning masters degrees. Civil engineering programs have traditionally emphasized specialization at the graduate level, and many programs still use the "civil" descriptor for programs that emphasize environmental engineering. However, an increasing number of institutions now offer baccalaureate and masters degrees designated as Environmental Engineering. Even though the number of baccalaureate degrees designated as environmental engineering is increasing (726 in 2005-2006), the number is small compared to civil engineering (8,935 in 2005-2006, ASEE, 2007). Accordingly, a common entry route to environmental engineering is via a baccalaureate degree in civil or other related engineering or science discipline followed by a masters degree in environmental engineering. While an appreciable number of baccalaureate graduates in environmental and related engineering disciplines begin employment in environmental engineering directly following the baccalaureate degree, more and more (estimated by the BOKWG as 35 percent) of them earn graduate degrees either directly following the baccalaureate degree or during their first few years of employment. A significant increase in knowledge applicable to environmental engineering has taken place over the past 50 years, while the number of credits required for the typical baccalaureate engineering degree has decreased. Accordingly, education beyond the baccalaureate degree is necessary for the engineer to understand processes and relationships essential to environmental engineering. An increasing number of employers of environmental engineers are recognizing this. Moreover, recent changes in the National Council of Examiners for Engineering and Surveying (NCEES) model licensure law require post-baccalaureate education prior to licensure by 2015. Licensing boards of some states are considering adoption of the post-baccalaureate education provisions of the model law.

C. Employment Sectors

Environmental engineers are employed in government service, consulting service, industry, and education. Although the skills and duties required of environmental engineers in each sector are similar, there are some differences.

- **Education** – The education sector is broad, ranging from continuing citizen and professional education provided by community colleges to graduate instruction provided by research universities.
- **Public Service** – Environmental engineering positions in public service cover a broad spectrum of duties ranging from operational management of water, wastewater or solid waste utilities at the city or regional level to administration of environmental regulations at the state and federal level, to environmental research. Most environmental engineers in responsible public service positions have post-baccalaureate education.
- **Industry** – Many environmental engineers are employed in the manufacturing, construction, and energy industrial sectors. Although compliance with environmental regulations is typically a major responsibility, many of these positions also have some responsibility for treatment facility operation and minor design.
- **Consulting Engineering Service** – Facility design has traditionally been a major responsibility for environmental engineers in consulting service. However, environmental engineering consulting has expanded to include more emphasis on Brownfield investigations, pollutant transport, regulatory guidance, sustainability, and facility operation. Most environmental engineers in responsible charge have masters degrees and an increasing number of environmental engineers in the consulting field have doctoral degrees. A growing number of consulting environmental engineers in responsible positions are becoming board certified by the AAEE.

D. Importance of Licensure and Specialty Certification

Licensure, like accreditation, is a credential of minimal acceptable engineering competence for protection of the public. Generally (and with some exceptions) engineering licenses are issued by State Boards of Engineering Examiners without limitation on the fields of engineering in which a person may practice. Some states exempt engineers working in industry and certain types of public service from licensing requirements, even though they may be involved in projects where public health, safety and welfare are issues. On the other hand, Specialty Certification identifies engineers who have been certified by their professional peers as having special capabilities in one or more areas of engineering practice. In 1965, AAEE began the first engineering peer specialty certification program in the United States. Although specialty certification does not carry any right or privilege, the Board Certified Environmental Engineer (BCEE) title does assist the public in identifying an engineer's technical expertise.

The importance of licensure and specialty certification varies among engineering disciplines and is generally most important in civil and environmental engineering. This importance also varies among environmental engineering employment sectors and is highest for consulting engineering service. Nevertheless, licensure and specialty certification are important as a visible professional credentials in all sectors to emphasize the engineer's responsibility for protecting public health, safety and welfare.

E. Technical Specialties of Environmental Engineering

Currently, most environmental engineering specialties have traditional roots that correlate to the historical development of the field from sanitary engineering and/or the promulgation of federal and state laws and regulations that divide the environment into silos (e.g., air, waste, drinking water, etc.). The result is that many professionals in consulting firms and government agencies work within groups that have similar traditional boundaries with titles often associated with a single medium or application within a medium. These boundaries are also reflected in the titles of various professional associations such as the Water Environment Federation, the American Water Works Association, and the Solid Waste Association of North America.

Berthouex et al., (1986) recognized the limitation of the traditional single media approaches and recommended integrated, air-water-land approaches to environmental engineering problems. Since then, environmental engineers have learned more about how ecosystems function, and how connected every component of the ecosystem is to the other. As a result of this emerging understanding of complexity, traditional specializations are being stretched and integrated to include knowledge from across specializations and in many cases across traditional disciplines. For example, assessing the fate and hazards associated with contaminants and their releases might have traditionally been the purview of an environmental engineer working with geochemists; today, this team may well include toxicologists, risk analysts, ecologists, and even social and political scientists. Thus, the areas of specialization within the environmental engineering discipline are changing in response to the demands from society for professionals to address complex environmental processes with a more comprehensive scope.

There is a trend away from specialization by media to provide a broader systems-based perspective on the nature of the problems and solutions relevant to environmental engineering. Although traditional media based areas of competence will continue to be used, many schools and consulting firms are describing their areas of competence in much more innovative and diverse ways such as.

- **By the nature of the contaminants** (toxic/carcinogenic, animal (including human) excreta, household wastes, etc.) – the nature of contaminant sources, releases, fate in the environment, treatment and risk all vary substantially based on the fundamental source of the contaminants. The biochemical oxygen demand, pathogen and nutrient loading problems associated with early sanitary engineering could identify a continuing area of specialization. However, toxic contaminants behave quite differently, are generally detected at much lower concentrations but still pose significant human and ecosystem risks, and require very different treatment or remediation technologies.
- **By the broad system of interest** – this has been defined as the natural versus engineered systems or the non-built and built environments. However, these distinctions are becoming blurred as green infrastructure and hybrid eco-design processes become more common. Many future environmental engineers will be characterized by the systems (both ecological and technological) being utilized in the design process rather than the traditional applications being designed.
- **By the nature of the processes being designed** – these could include biological, physical-chemical, fluid flow and transport. Fundamental transformation and transport processes are common across natural and engineered systems. A technical specialization in biological processes, for example, would require depth in microbial processes ranging from the molecular to the reactor scale. This specialization could lead towards the application of these processes to constructed wetlands, municipal wastewater treatment processes, solid waste landfills or in-situ groundwater remediation design. The fundamental science and engineering would be common across all of these application areas.
- **By the nature of the intervention** – such as minimization (including management practices or engineered solutions), treatment, or assimilation. Engineered solutions can take many forms. Many environmental engineers now consider themselves specialists in the area of minimizing releases or waste generation, while others focus primarily on environmental assimilation of pollutants.

In addition to the changes in the way we segregate the current practice of environmental engineering into specializations; new specializations are also emerging based on recent innovations in research and the expansion of the discipline. Areas of emerging research, innovation and practice in environmental engineering include ecological engineering, restoration engineering, sustainability engineering, and risk assessment engineering. These emerging areas of specialization utilize approaches that may include green infrastructure design and sustainability design.

III. FUTURE ROLE OF THE ENVIRONMENTAL ENGINEER

The future of humankind on the earth will, based on currently available historical information, be profoundly influenced by two phenomena, continued human population growth and depletion of natural resources, particularly fossil fuels. These two phenomena may, in turn, influence climate and lead to water and food scarcity. Environmental engineers must be prepared not only to react to changes in climate and resource availability but also to help manage that change through sustainable engineering.

A. Population Growth and Declining Resources

A plot of human population from prehistoric times to the present shows that we are in a period of unprecedented growth in the numbers of humans inhabiting earth. The current population is six billion and is increasing by 80 million per year. This growth has resulted in increased use of fossil fuels, water, and mineral resources for agriculture, transportation, materials, heat and other human needs. Environmental engineers will need to assist society in the management, design and development of the built environment for more humans while making more efficient use of water, land, materials, and energy. At the same time, they will have to manage the by-products of society while helping to provide for more renewable energy sources.

B. Climate

The earth's climate has changed throughout history and currently is in a warming period (IPCC, 2007). Society will have to adapt to an altered climate. Violent weather events may become more frequent. The boundary between cold and warm regions and between wet and dry regions may shift. Throughout these events, humankind may be stressed, but will adapt. Increased water scarcity will probably be one of the most serious impacts of population growth and climate change, and will likely be felt most acutely by agriculture and by cities located in arid regions. Indirect water reuse will become the norm, and direct, large-scale potable water reuse will begin. The potential of the seas will be brought into play as a major water supply source. Environmental engineers will need to enhance their competence related to water reuse, disinfection, and distribution. They will also need new skills for coping with adverse climatic and weather conditions.

C. Water, the Developing World and Human Health

Clean water and environmental sanitation are intrinsically related. Much of the world's population does not have access to either clean water or adequate sanitation facilities. Consider the following:

The United Nations (UNEP, 2007; UN Water, 2007) and World Health Organization (WHO and UNICEF 2004) report that:

- Approximately 2.5 billion people do not have access to improved sanitation facilities, and 1.1 billion people lack access to clean water.
- By 2025, nearly 2 billion people will be living in regions of absolute water scarcity, and two-thirds of the world population could be under conditions of water stress.

Epidemiological studies reported by Clasen and Cairncross (2004) estimate that waterborne diarrheal diseases:

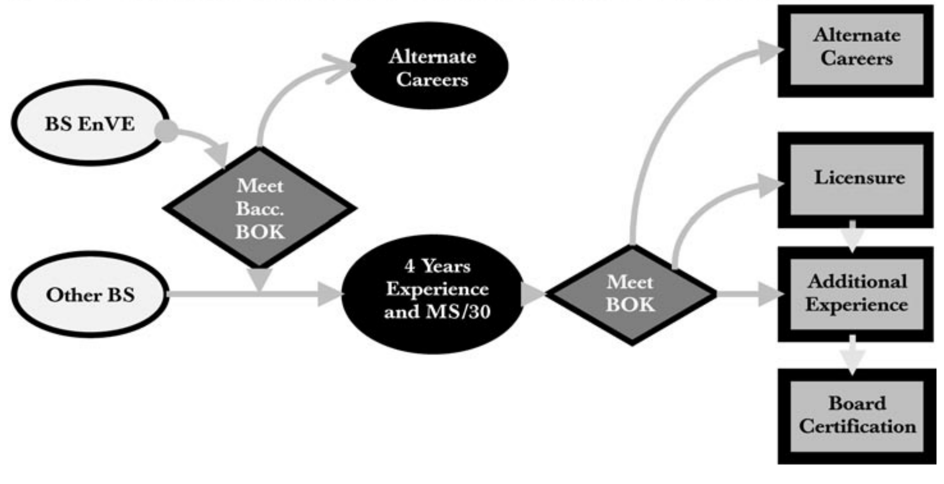
- Kill 2.5 million people per year, mostly children under five years old (Kosek et al. 2003);
- Account for about 5.7% of the global disease burden with 4 billion cases per year (Pruess et al. 2002); and
- Account for 21% of deaths of children under five years old in developing countries (Parashar et al. 2003).

Clearly, the water scarcity, sanitation and health problems are most acute in the developing world, and these problems can lead to conflict. Environmental engineers are already working on these problems and this activity will increase as more attention and resources are directed at these problems.

D. Sustainability

Sustainability is the ability to meet human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for the future (ASCE, 2008). Sustainable engineering meets these human needs. Humankind is becoming aware that sustainability is important, but so far has taken only limited action toward achieving sustainability. More serious actions will be taken in the future as resources become more depleted. The environmental engineer will need to be a leader in implementing actions that enhance sustainability. The role of the environmental engineer in this effort will most likely focus on water and on sustainable material and energy use in the built environment.

FIGURE 1 BOK and the Education and Professional Development of an Environmental Engineer



E. Multi- and Interdisciplinary Interactions

It is apparent from the foregoing discussion that addressing the environmental impacts of population growth, resource depletion, climatic change, water scarcity, and sanitation will require a team approach. Many engineering specialties will be involved as well as scientists, politicians, government personnel, and a variety of stakeholders. The environmental engineer will be best equipped to lead and coordinate the multidisciplinary engineering team in addressing environmental impacts. It follows that the environmental engineer practicing at full professional capacity should have the technical breadth to relate to engineers and specialists from other disciplines as well as the non-technical breadth to positively influence society and stakeholders.

IV. DEVELOPMENT OF THE ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE (EnvE BOK)

A. Outcomes Based Structure of the BOK

The EnvE BOK is defined by outcomes consistent with ABET 2000 Criteria, but placed in the context of environmental engineering. For each outcome, performance levels are specified, and relevant knowledge domains are identified. As used herein:

- An **Outcome** states or describes an ability to perform a task,
- A **Performance Level** defines the intellectual depth of the task and relates to Bloom's cognitive levels.
- A **Knowledge Domain** is an organized field of human cognition such as history or mathematics.

Core competencies are defined in outcomes; knowledge areas required for each outcome are identified for each outcome. The EnvE BOK provides a guide for curriculum development and reform, and provides a means for employers to better understand the knowledge base of environmental engineers. The competence and skill requirements are in agreement with those identified at the 1991 and 1996 Environmental Engineering Education Conferences (Baillod et al, 1991; Marini, 1996).

B. Education for the BOK

The EnvE BOK is fulfilled through a combination of baccalaureate-level work, masters-level work, and professional experience. Fulfillment of the EnvE BOK does not require a BS EnvE degree; those with BS degrees in science or other engineering fields could meet the baccalaureate-level requirements as part of their post-baccalaureate education. Fulfilling the EnvE BOK will prepare one not only for professional licensure, but also for alternate careers that do not require licensure. Therefore, the BOK was designed to broadly prepare professionals for practice of EnvE that includes, but is not limited to, planning,

TABLE 1 Environmental Engineering BOK Outcomes

Outcome Number and Title	Outcome
Foundational Outcome	
1. Basic Environmental Math & Science (BEMS) Knowledge	Mathematics; physics; chemistry; biological science; earth science, mass, energy and momentum conservation and transport principles needed to understand and solve environmental engineering problems.
Enabling Knowledge and Skills Outcomes	
2. Design and Conduct Experiments	Design and conduct experiments necessary to gather data and create information for use in analysis and design
3. Modern Engineering Tools	The techniques, skills, and modern engineering tools necessary for engineering practice
4. In-Depth Competence	Advanced knowledge and skills essential for professional practice of environmental engineering
5. Risk, Reliability and Uncertainty	The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety
6. Problem Formulation and Conceptual Analysis	Problem formulation and analysis based on proper environmental engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions
7. Creative Design	Design of a system, component or process to meet desired needs related to a problem appropriate to environmental engineering.
8. Sustainability	Integration of sustainability into the analysis and design of engineered systems
9. Multimedia Breadth and Interactions	Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems
10. Societal Impact	Societal impact of public policy affecting environmental engineering issues and solutions.
11. Contemporary and Global Issues	Globalization and other contemporary issues vital to environmental engineering
Professional Outcomes	
12. Multi-disciplinary Teamwork	Skills and expertise of multiple disciplines used to address complex engineering problems as a team
13. Professional and Ethical Responsibilities	Professional and ethical issues in environmental engineering
14. Effective Communication	Effective communications when interacting with the public and the technical community
15. Lifelong Learning	Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns
16. Project Management	Principles of project management relevant to environmental engineering
17. Business and Public Administration	Business knowledge and communication skills necessary to the administration of both private and public organizations
18. Leadership	Engagement, motivation and leadership of others to achieve common vision, mission and goals

design, teaching, applied or fundamental research, public administration, or operations. It was recognized that individuals receiving a degree in EnvE may not elect to pursue post-baccalaureate education related to EnvE and may never practice EnvE, but rather may seek other professional degrees, such as law or medicine, and follow an entirely different career path. Therefore some paths beginning with a baccalaureate degree in EnvE may not lead to complete BOK fulfillment. With this in mind the baccalaureate-level work comprising the BOK was designed to provide comprehensive undergraduate preparation for a broad range of careers. Figure 1 shows the role of the EnvE BOK in the education and development of an environmental engineer.

C. Environmental Engineering Outcomes

The Environmental Engineering Outcomes have been arranged in three groups as shown in Table 1. The **first group** includes an outcome that provides foundational basis for environmental engineering education. This fundamental outcome ensures abilities in science, mathematics, and areas of discovery and design that will enable environmental engineers to succeed in a future of technological change and innovation.

The **second group** identifies outcomes essential to the problem-solving process. Problem solving involves problem definition, identifying constraints and alternatives, analyzing alternatives, selecting and optimizing the appropriate solution, and implementation. The process is iterative, requiring problem redefinition and refining as information is acquired, followed by verification of results during implementation and after the solution is implemented. Problem solving involves both analytical and creative skills. Analytical skills include the ability to comprehend, define and analyze the problem, while creativity is necessary in identifying alternative solutions and envisioning possible unanticipated consequences of the solution. Environmental engineering problem formulation and solution must be accomplished in the context of sustainability, must meet societal needs, and be sensitive to global implications. The ability to envision the individual steps in a solution and their results can only be gained through practice, acquisition of subject specific knowledge and understanding, and experience using state-of-the art tools.

The **third set of outcomes** defines professional skills, knowledge and attributes that environmental engineers must have to successfully implement solutions. Fulfilling these outcomes will enable them to communicate well, to effectively manage projects, and to successfully engage other engineers and the public. Throughout their careers, environmental engineers must remain cognizant of changing technology and issues. The public must appreciate the role environmental engineers may play as leaders as well as society - particularly when the solutions to environmental engineering issues recommended require policy changes. Public confidence in these solutions requires that environmental engineers conduct themselves ethically.

D. Knowledge Domains

Knowledge domains identify specific areas of learning that are essential to accomplishing the outcome. They are not necessarily curricular courses. They may, for example, represent a single lecture within a course, or

FIGURE 2 Matrix of Outcomes and Knowledge Domains

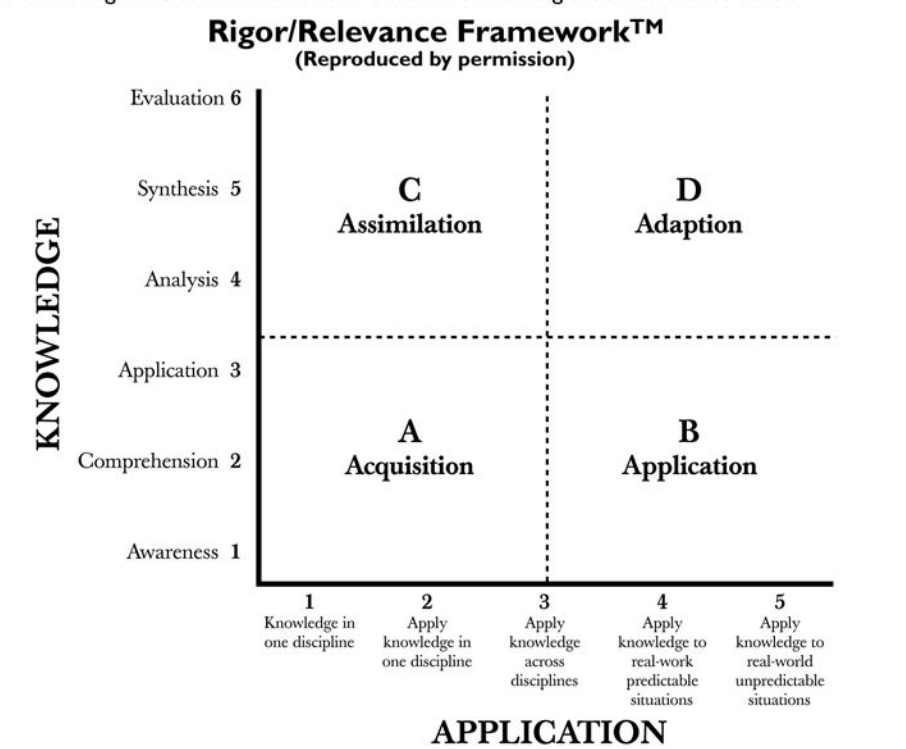
Knowledge Domain Required	Outcome 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mathematics, Computer Languages	■	■	■	■	■	■	■	■	■	■	■				■			
Physics, Mechanics	■	■		■	■			■	■	■	■				■			
Chemistry	■	■		■	■	■	■	■	■	■	■				■			
Biology and Ecology	■	■		■	■		■	■	■	■	■				■			
Conservation of Mass	■			■	■	■	■	■	■		■				■			
Conservation of Energy	■			■	■		■		■		■				■			
Mass Transport	■			■	■		■		■		■				■			
Heat Transport	■			■	■						■				■			
Fluid Mechanics	■			■	■		■	■	■		■				■			
Earth Science	■			■	■	■		■	■		■				■			
Systems Analysis	■	■	■	■	■	■	■	■	■	■	■				■			
Probability and Statistics		■	■		■			■	■		■				■			
Humanities, Social Studies						■	■			■	■		■	■	■	■	■	■
Economics							■	■	■	■	■				■		■	■
Business Management						■		■	■		■	■	■		■		■	■

they may be topics within multiple courses taught at different levels. Figure 2 provides a rubric with knowledge domains identified and mapped to the 18 outcomes.

E. Performance Levels

Fulfillment of outcomes occurs at three points in the professional development of an environmental engineer, at the completion of a baccalaureate degree in environmental engineering, at the completion of a masters degree or 30 hours post-baccalaureate, and after four years of professional practice. A level of achievement for BOK fulfillment at each of these points is described using a two-dimensional scale that characterizes performance of the outcome in terms of its cognitive rigor and its practical relevance. The Rigor/Relevance Framework™ (Figure 3) was created in 1997 by Willard R. Daggett, Ed.D. of the International Center for Leadership in Education (Daggett, 2005). The application of this scale is more clearly seen in the EnvE BOK Report Appendix where Outcomes are mapped to cognitive levels and practical relevance.

FIGURE 3 Rigor/Relevance Framework Used in Formulating the Performance Levels



The Y-axis of Figure 3 utilizes Bloom's Taxonomy to describe cognitive levels of learning and application. This taxonomy was first developed in 1956 by Benjamin Bloom, who headed a group that developed a classification of levels of intellectual behavior important in learning.

Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order which is classified as evaluation. Unfortunately, Bloom found that over 95 percent of typical test questions students encounter require them to think only at the lowest possible level – knowledge and the recall of information. In the EnvE BOK, it is clear that the capacity to use this knowledge for engineering applications, synthesis and evaluation of alternatives must be defined. Each of the cognitive levels is defined below.

1. Knowledge (C1)

Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories.

However all that is required is the bringing to mind of the appropriate information – nothing further. Knowledge represents the lowest level of learning outcomes in the cognitive domain.

2. Comprehension (C2)

Comprehension is defined as the ability to grasp the meaning of material. This may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond the simple remembering of material, and represent the lowest level of understanding.

3. Application (C3)

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension.

4. Analysis (C4)

Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material.

5. Synthesis (C5)

Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns or structure.

6. Evaluation (C6)

Evaluation is concerned with the ability to judge the value of material (statement, theory, equation, research report) for a given purpose. The judgments are based on definite criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) that may need to be determined or already defined. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all the other categories, plus conscious value judgments based on clearly defined criteria.

Studies have shown that students understand and retain knowledge best when they have applied it in a practical, relevant setting. A teacher who relies on lecturing does not provide students with optimal learning opportunities. Instead, students go to school to watch the teacher work.

Daggett extended the commonly used Bloom's taxonomy scale to include a second dimension related to the relevance or applicability of the material. The relevance scale spans from knowledge in one discipline to application of knowledge in real world unpredictable situations as described below:

1. Knowledge in one discipline (A1)
2. Apply knowledge in one discipline (A2)
3. Apply knowledge across disciplines (A3)
4. Apply knowledge to real world predictable situations (A4)
5. Apply knowledge to real world unpredictable situations (A5)

Combining the cognitive rigor (C levels), with the applicative relevance (A levels) gives the four quadrants of Figure 3. Students need to begin with knowledge in single disciplines (quadrant A) and move upwards and to the right towards quadrant D. These quadrants include:

- **Quadrant A – Acquisition (typical C2, A2)**: Students gather and store bits of knowledge and information. Students are primarily expected to remember or understand this knowledge.
- **Quadrant B – Application (typical C2, A4):** Students use acquired knowledge to solve problems, design solutions, and complete work. The highest level of application is to apply knowledge to new and unpredictable situations.
- **Quadrant C – Assimilation (typical C4, A2):** Students extend and refine their acquired knowledge to be able to use that knowledge automatically and routinely to analyze and solve problems and create solutions.
- **Quadrant D – Adaptation (typical C5, A4):** Students have the competence to think in complex ways and to apply their knowledge and skills. Even when confronted with perplexing unknowns, students are able to use extensive knowledge and skill to create solutions and take action that further develops their skills and knowledge.

As with many professions, the combination of education, training and experience needs to help guide an engineer through these quadrants in order to operate at the highest levels of both cognitive function and relevant applications in order to meet the expectations of a professional engineer. Thus, the expected performance levels for the various outcomes have been described using the two dimensional cognitive rigor (C dimension) and applicative relevance (A dimension).

V. DETAILED DESCRIPTION AND PERFORMANCE LEVELS FOR OUTCOMES

A more detailed description and application of the rigor/relevance framework for the Outcomes listed in Table 1 is given in the Appendix. For each outcome, the expected performance is described at three career levels:

- **Baccalaureate Level:** This applies to engineers earning the Bachelor of Science in Environmental Engineering degree.
- **M/30 Level:** This applies to engineers who hold baccalaureate degrees in environmental engineering or in other engineering or science specialty and who have earned a masters degree or at least 30 semester credits beyond the baccalaureate. It is assumed that these individuals would also meet the baccalaureate level outcomes. It is understood that engineers holding baccalaureate degrees in fields other than environmental engineering may require more then 30 semester credits to attain this performance level.
- **After Professional Experience:** This applies to engineers who meet the M/30 level and who have had at least four years of professional environmental engineering experience with mentoring from more experienced engineers.

At each level of expected performance, the rigor and relevance of the outcome are identified using Bloom's Cognitive Level

TABLE 2 Rigor/Relevance Performance Matrix Table for Draft Outcome 1

Foundational Outcome						
Level of Achievement						
Cognitive Level:	**C1 Knowledge**	**C2 Comprehension**	**C3 Application**	**C4 Analysis**	**C5 Synthesis**	**C6 Evaluation**
Practical Relevance:	**A1 Within Discipline**	**A2 Within Discipline**	**(B):A2 (M30):A3 Across Disciplines**	**A3 Complicated Situations**	**A5 Complex Situations**	**A5 Complex Situations**
Outcome 1						
Basic Environmental Math & Science (BEMS) for Environmental Engineering	***Define*** key factual information related to the knowledge of domains of mathematics, physics, chemistry, biology, ecology, conservation and transport principles, and earth sciences (BEMS) (B)	***Explain*** key concepts and problem-solving processes involved in each knowledge domain of the BEMS. (B)	***Apply*** each knowledge domain of the BEMS to solve well-defined problems appropriate to environmental engineering. (B) Apply knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering. (M/30)	***Analyze*** a complex problem to determine relevant BEMS knowledge domains. (M/30)	***Create*** new ways to apply BEMS knowledge domains to environmental engineering. (E+*) *beyond four years of experience	***Evaluate*** innovative engineering approaches to solve real-world problems appropriate to environmental engineering **using knowledge domains of the BEMS.** (E)

(C1 to C6) and Daggett's Relevance Level (A1 to A5).

In addition to the tabular text descriptions of the Outcomes given in the Appendix, the Draft BOK also describes the outcomes using Rigor/Relevance Performance Matrix Tables. This is shown in Table 2 for Draft Outcome 1. The matrix tables are convenient for comparing expected performance between levels and outcomes.

VI. IMPLEMENTATION OF THE EnvE BOK

Educators, students, young engineers and senior practitioners all share responsibility in implementing the EnvE BOK. Educators and students should be familiar with the EnvE BOK because it defines the outcomes of an environmental engineering education. From a faculty point of view, the EnvE BOK can guide curriculum and expectations of students; from a student point of view, the EnvE BOK can guide expectations of their technical and non-technical educational experience. As stakeholders in engineering education, practitioners, managers, and leaders of public and private engineering organizations should be familiar with the EnvE BOK. The depth and breadth of the young environmental engineer's early professional experiences are critical to fulfilling the EnvE BOK. Senior practitioners should take an active role to help young environmental engineers continue the learning process toward fulfillment of the EnvE BOK and professional licensure.

The development of the EnvE BOK is a continuous process of testing and improvement. As it is implemented, practitioners and educators must evaluate the EnvE BOK and determine whether all issues necessary to the practice of environmental engineering have been addressed and whether the outcomes can be achieved at the level recommended at the point in professional development indicated. It is recommended that such evaluation be accomplished utilizing task forces created by organizations serving significant numbers of environmental engineers, such as the AAEE sponsoring organizations. Practitioner task forces should examine the EnvE BOK to ensure that engineers will be educated to meet the needs of the future, that the practitioner's role has been correctly identified, and that the levels of achievement are correct. Educators should conduct a curriculum reality check. A representative number of EnvE undergraduate and graduate programs should be identified and asked to evaluate whether curricula can be reasonably designed to adopt the EnvE BOK. Educators should also determine whether the levels of achievement are correctly applied. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the EnvE BOK should be used for accreditation, licensing, and promotion of the profession.

The draft EnvE BOK summarized here is currently undergoing a peer review by environmental engineering educators and practitioners. Comments are welcome and should be directed to Dr. Debra Reinhart at reinhart@mail.ucf.edu.

ACKNOWLEDGEMENT

Travel support provided by the National Science Foundation for meetings of the Working Group is gratefully acknowledged.

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APPENDIX — DRAFT OUTCOMES

Outcome 1: Basic Environmental Math and Science (BEMS) Knowledge for Environmental Engineering

Mathematics; physics; chemistry; biological science; earth science, mass, energy and momentum conservation and transport principles needed to understand and solve environmental engineering problems

Outcome Explanation: Underlying the professional role of the environmental engineer as the master integrator and technical leader is a firm foundation in mathematics, physics, chemistry, biology, ecology, and earth science. The environmental engineer draws on these knowledge domains along with principles of conservation and transport of mass, momentum and energy to analyze natural systems and to design, construct, and manage engineered systems.

Baccalaureate Level:

- **Define** key factual information related to the knowledge domains of the BEMS. (C1, A1)
- **Explain** key concepts and problem-solving processes involved in each knowledge domain of the BEMS. (C2, A2)
- **Apply** each knowledge domain of the BEMS to well-defined problems appropriate to environmental engineering. (C3, A3)

M/30 Level:

- **Analyze** a complex problem to determine relevant BEMS knowledge domains. (C4, A3)
- **Apply** knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering. (C3, A3)

After Professional Experience:

- **Evaluate** innovative engineering approaches to solve real-world problems appropriate to environmental engineering using knowledge domains of the BEMS. (C6, A5)

Outcome 2: Design and Conduct Experiments

Design and conduct experiments necessary to gather data and create information for use in analysis and design

Outcome Explanation: An experiment is a procedure carried out in order to discover information, to test or establish a hypothesis, or to determine characteristics of environmental media or processes. Environmental engineers frequently conduct experiments to gather data and create information for use in analysis and design. Such experiments may be conducted in the field or the laboratory or may involve numerical simulation. These experiments would involve some direct measurements or simulations of physical, chemical and biological characteristics of water, air and soil or processes used in their treatment, remediation or restoration. To efficiently design and conduct experiments, the environmental engineer must be familiar with the appropriate tools and should have the ability to interpret the results.

Baccalaureate Level:

- **Identify** the procedures and equipment required to conduct common experiments appropriate to environmental engineering. (C1, A1)
- **Explain** the purpose, procedures, equipment and practical application of experiments appropriate to environmental engineering. (C2, A2)
- **Conduct** experiments appropriate to environmental engineering. (C3, A2)
- Use statistics to **analyze** experimental uncertainties and error and interpret results. (C4, A2)
- **Design** an experiment based on accepted procedures and measurements to develop specific information or to test a specific

hypothesis appropriate to environmental engineering.(C5, A2)

M/30 level:

- **Design and conduct** experiments using appropriate state-of-the-art tools to develop specific information or to test a specific hypothesis related to a predictable problem appropriate to environmental engineering. (C3, C5, A3/A4)
- **Analyze and interpret** the results and explain the resulting information using appropriate communication tools. (C4, A3/A4)
- **Design** an experiment to develop specific information or to test a specific hypothesis related to a complex problem appropriate to environmental engineering.

After Professional Experience:

- **Evaluate** the effectiveness of an experiment designed to obtain information related to a complex problem appropriate to environmental engineering, communicate the evaluation to stakeholders. (C6, A5)

Outcome 3: Use of Modern Engineering Tools

The techniques, skills, and modern engineering tools necessary for engineering practice

Outcome Explanation: A practicing environmental engineer must be able to apply state-of-the-art tools in analyzing problems and creating solutions and designs. Such tools include, as examples, measurement tools and techniques, programming languages, and software for graphics, GIS, modeling, statistical analysis and risk analysis.

Baccalaureate Level:

Identify and **describe** the engineering tools available to appropriate issues in environmental engineering problems. (C1, A1)

- **Select** the most appropriate tool for application to various types of engineering problems and projects. ((C2, A2)
- **Apply** modern engineering tools to the various elements of engineering problem solving and project analysis for well-defined problems. (C3, A2)

M/30 Level:

- **Recognize** the limitations of the various tools with respect to appropriateness, accuracy, consistency, sensitivity. (C2, A2)
- **Apply** modern engineering tools to multidisciplinary environmental engineering problem solving. (C3, A3)

After Professional Experience::

- **Evaluate** the benefits, risk, and uncertainty associated with the use of specific tools in analysis of environmental engineering projects. (C6, A5)

Outcome 4: In-Depth Competence

Advanced knowledge and skills essential for professional practice of environmental engineering

Outcome Explanation: In-depth competence based on advanced knowledge and skill is essential for professional practice of environmental engineering. This competence may be attained in a traditional specialty such as water/wastewater, it could span a range of traditional specialties, or it could focus on an emerging or non-traditional area such as ecological engineering or aspects of sustainability.

Baccalaureate Level:

- **Recognize and describe** the need for in-depth competence for solution of complex environmental problems. (C1, A2)
- **Describe** the traditional specialties as well as some emerging specialties appropriate to environmental engineering. (C2, A2)
- **Apply** specialized tools, methodology or technology to solve well-defined problems. (C3, A2)

M/30 Level:

- **Analyze** a predictable environmental process or system in a traditional or emerging area. (C4, A4)
- **Design** a predictable environmental process or system in a traditional or emerging area. (C5, A3)

After Professional Experience:

- **Design** and **implement** a complex system or process in a traditional or emerging area. (C5, A4)

Outcome 5: Risk, Reliability, and Uncertainty

The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety

Outcome Explanation: From an environmental engineering context, risks to humans or environmental systems can occur from exposure to physical, chemical and biological hazards or from the failure of engineered systems designed to protect the environment and the public health, welfare and safety. Risk is often defined as a measure of the probability and severity of adverse effects. Its assessment includes definition of context and system, exposure assessment, hazard identification, quantification of risk, and assessment of risk relative to specified criteria. Environmental engineers must use these assessments to determine what can be done, what options are available, and, the associated trade-offs in terms of costs, benefits, and risks, and the impacts of current decisions on future options (University of Virginia Center for Risk Management of Engineered Systems: http://www.sys.virginia.edu/risk/overview.html).

Baccalaureate Level:

- **Identify** potential hazards, exposure pathways, and risks to the environment and the public health, welfare and safety associated with exposure to physical, chemical and biological hazards. (C1, A1)
- **Identify** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and the resulting consequences of such a failure. (C1, A1)
- **Explain** the significance of uncertainties in data and knowledge on the performance and safety of an engineering system. (C2, A2)
- **Apply** the principles of probability and statistics to the design of a simple engineered component using data or knowledge-based uncertainties. (C3, A3)
- **Determine** the potential exposure and risk to the environment and the public health, welfare and safety for well-defined chemical and biological exposure and hazards. (C3, A3)

M/30 Level:

- **Analyze** the potential exposure and risk to the environment and exposed populations for multiple chemical and biological exposure routes and hazards. (C4, A4)
- **Analyze** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and quantify the resulting consequences of such a failure. (C4, A4)
- **Design** an engineered system applying the principles of probability and statistics to uncertainties in data or knowledge. (C5, A4)

After Professional Experience::

- **Assess** the risks of various engineering alternatives and integrate this assessment into the recommendation of an alternative. (C6, A5)
- **Employ** quantitative tools to analyze risk and reliability. (C6, A5)

Outcome 6: Problem Formulation and Conceptual Analysis

Problem formulation and analysis based on proper environmental engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions

Outcome Explanation: Conceptual design includes assessing the engineering situation, articulating the problem through technical communication (written and/or oral), formulating alternative approaches, evaluating the alternatives, and recommending feasible solutions. Approaches should include systems analysis, development of solutions, both routine and creative; evaluation of alternative solutions and their environmental and economic consequences; and use of iterative process analysis and selection of the most appropriate solution(s), employing critical thinking and synthesis of fundamental knowledge appropriate to environmental engineering.

Baccalaureate Level:

- **Explain** key concepts related to problem recognition, articulation and solution. (C2, A2)
- **Recognize** difficulties requiring innovative problem definition and solutions. (C2, A2)
- **Analyze** a well-defined problem to identify the root cause. (C4, A2)

M/30 Level:

- **Apply** advanced level technical knowledge and problem analysis/solving skills to complex multidisciplinary problems. (C3, A3/A4)
- **Analyze** problems appropriate to environmental engineering having unpredictable or incomplete parameters to determine their root causes. (C4, A3)
- **Analyze** feasibility and appropriateness of predictable solutions as alternatives to conventional solutions to problems. (C4, A3)

After Professional Experience:

- **Synthesize** experience-acquired knowledge and skills to anticipate and identify unpredictable problems. (C5, A5)
- **Develop** means for supplementing inadequate data or definition. (C5, A5)
- **Evaluate** innovative solutions to complex real world problems and compare with conventional solutions based on environmental and economic consequences of implementation. (C6, A5)

Outcome 7: Creative Design

Design of a system, component or process to meet desired needs related to a problem appropriate to environmental engineering.

Outcome Explanation: Design is a creative and discovering process using iterative steps. Activities such as problem definition, stipulating problem specifications, analysis, performance prediction, implementation, and assessment are parts of this process. The design process is open-ended, frequently with a number of feasible solutions. Successful design requires creative and critical thinking, appreciation of uncertainties involved and use of engineering judgment.

Baccalaureate Level:

- **Define** problem objectives and specify design criteria. (C2, A3)
- **Recognize** realistic constraints such as economics, environmental, social, political, ethical, health and safety, constructability and sustainability factors appropriate to environmental engineering. (C2, A3)
- **Apply** creativity and knowledge domains of BEMS to design a system or process to meet desired needs. (C3, A3)
- **Analyze** predictable situations to determine design needs and requirements. (C4, A3)

M/30 Level:

- **Apply** creativity and knowledge domains of BEMS to design a real world system or process to meet desired needs. (C3, A4/A5)
- **Analyze** real world situations to determine design needs and requirements. (C4, A3/A4)
- **Assess** compliance with customary standards of practice, client's needs, and relevant constraints appropriate to environmental engineering to develop solutions to real world problems. (C5, A4)

After Professional Experience:

- **Assess** the needs of the public and other stakeholders in formulating design constraints and objectives. (C4, A3/A4)
- **Understand** the design of a predictable system, component or process appropriate to environmental engineering. (C5, A4)
- **Understand** the interactions among planning, design, life-cycle assessment, construction and operational management appropriate to environmental engineering. (C6, A4)
- **Evaluate** design proposals appropriate to environmental engineering as part of the peer review process. (C6, A4)

Outcome 8: Sustainability

Integration of the sustainability into the analysis and design of engineered systems

Outcome Explanation: As defined by several engineering professional societies, the constraints imposed by the long-term sustainability of our natural and social systems must be a critical factor in the design and selection of engineered systems. For example, in June 2002, AAES, AIChE, ASME, NAE, and NSPE signed the following declaration (NAE, "Dialog on the Engineers' Role in Sustainable Development – Johannesburg and Beyond," 2002).

> *Creating a sustainable world that provides a safe, secure, healthy life for all peoples is a priority for the US engineering community. … Engineers must deliver solutions that are technically viable, commercially feasible and, environmentally and socially sustainable.*

This has led to a statement adopted in 2006 by NSPE that was added to its Code of Ethics as a professional obligation of engineers:

> *Engineers shall strive to adhere to the principles of sustainable development in order to protect the environment for future generations.*

For the purposes of this document, the term sustainability is defined (ASCE, 2008) as:

> *Sustainability is the ability to meet human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for the future. Sustainable engineering meets these human needs.*

The environmental engineer has a critical role in the emerging subdiscipline of sustainable engineering. It is expected that environmental engineers have sufficient understanding of natural system processes, that is - how our earth functions, to help define the extent of environmental alteration that may result from different engineered systems. At the same time, they must also integrate sustainability principles into the engineered systems they themselves design, build or operate to protect environmental and human health and well being.

Baccalaureate Level:

- **Recognize** life-cycle principles in the context of environmental engineering design. (C1, A2)
- **Identify** components in an engineered system that are not sustainable. (C2, A2/A3)
- **Explain** the scientific basis of natural system processes and the impacts of engineered systems on these processes. (C2, A2/A3)
- **Explain** the need for and ethics of integrating sustainability throughout all engineering disciplines and the role environmental engineers have in this. (C2, A2/A3)
- **Quantify** environmental releases or resources consumed for a given engineered process. (C3, A3)

M/30 Level:

- **Analyze** the sustainability of an engineered system using traditional or emerging tools (e.g., industrial ecology, life cycle assessment, etc.). (C4, A3/A4)
- **Ascertain** where new knowledge or forms of analysis are necessary for sustainable design. (C4, A3/A4)
- **Design** traditional or emerging engineered systems using principles of sustainability. (C5, A4)

After Professional Experience:

- **Design** a complex system, process, or project to perform sustainably. (C5, A5)
- Evaluate the sustainability of complex systems, whether proposed or existing (ASCE, 2008). (C6, A5)

Outcome 9: Multimedia Breadth and Interactions

Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems

Outcome Explanation: Environmental engineers must have a holistic view of the environment so that pollutants removed from one medium do not cause problems by transfer to another. They must be able to apply fundamental principles to fate and transport of substances not only within a single medium but also to the transfer between media in natural or engineered systems. It follows that environmental engineers must understand the principles that govern inter-media transfer and must be able to consider the impact of this transfer in problem formulation and design. The situation is complicated by laws and regulations that consider only single media.

Baccalaureate Level:

- **Explain** how inter-media transfer is relevant to environmental engineering problems. (C2, A2)
- **Apply** conservation and transport principles to determine the fate of substances in air, water, and soil for well-defined situations. (C3, A3)
- **Apply** the fundamental principles governing transfer of substances between phases to well-defined situations e.g. where equilibrium assumptions apply. (C3, A3)

M/30 Level:

- **Apply** fundamental principles governing inter-media transport and fate of substances to a complex situation, e.g. where mass transfer is rate limited. (C3, A4)
- **Analyze** a system that incorporates inter-media transport and fate of pollutants. (C4, A3/A4)

After Professional Experience:

- **Design** a system that incorporates inter-media transport and fate of substances. (C5, A5)
- **Appraise** the laws and regulations that pertain to the air, water and land environment applicable to a specific practice area. (C6, A5)

Outcome 10. Societal Impact and Environmental Policy

Societal impact of environmental engineering issues and solutions; engineering and communication skills that influence and implement public environmental policy

Outcome Explanation: Public policy consists of political decisions for implementing programs to achieve societal goals (Cochran, C.L. and Eloise F. Malone (2005), *Public Policy: Perspective and Choices, Third Edition*, Lynn Rieneer Publishers, Boulder, CO.). As concluded in NAE's *The Engineer of 2020*, as technology becomes more ingrained in our lives, the convergence of engineering and public policy must increase. Because environmental engineers are regularly involved in the implementation of public environmental policy, they have a unique understanding of the elements of good environmental policy. It follows that they should be involved as stakeholders in the process of establishing environmental policies. Further, environmental engineers should recognize societal impacts of engineering activities, should communicate these impacts to stakeholders, and should consider stakeholder inputs in developing solutions.

Baccalaureate Level:

- **List** some important environmental policies as stated in international accords and federal laws. (C1, A2)
- **Recognize** potential societal impacts of a solution to an environmental problem. (C2, A3)
- **Discuss** and **explain** important processes involved in setting public environmental policy. (C2, A3)

After Professional Experience:

- **Describe** and **explain** environmental policy in some detail in some area of environmental practice. (C2, A3)
- **Apply** knowledge of societal structure and dynamics when seeking solutions to environmental problems. (C3, A3)
- **Participate** as a citizen stakeholder in the development of public environmental policy. (C3, A3)

Outcome 11: Globalization and other Contemporary Issues

Globalization and other contemporary issues vital to environmental engineering

Outcome Explanation: Contemporary issues are problems and topics of emerging importance or recent discovery. Globalization refers to an integration of processes or delivery systems that transcends national, cultural and language differences. For example, awareness of the impact of inadequate sanitation on public health in many parts of the developing world and the impact of human activity on climate change are issues that are both global and contemporary. The environmental engineer must be able to function in a global system for delivery of engineering projects and services practice, taking into consideration the culturally appropriateness of technology. In addition, the environmental engineer must be aware of emerging contemporary issues and of their impact on the profession.

Baccalaureate Level:

- **Explain** some barriers to the delivery of environmental engineering services in a global context. (C2, A3)
- **Utilize** modern tools to identify and understand contemporary issues. (C3, A3)
- **Define**, **analyze** and **propose** solutions to well-defined environmental engineering problems that are constrained by global and contemporary issues. (C4, A3)

M/30 Level:

- **Describe** how globalization of technology has influenced design and/or project delivery within a technical area of environmental engineering. (C2, A3)
- **Participate** in discussion and debate focused on globalization and contemporary issues and their relationship with and potential impact on public health and the environment. (C3, A3)
- **Synthesize** information on contemporary issues to provide perspective on relevance to environmental engineering problems. (C5, A4)

After Professional Experience:

- **Evaluate** the impact of an important globalization and/ other contemporary issue on design and/or delivery of an environmental engineering project or case study. (C6, A5)

Outcome 12: Multi-Disciplinary Teamwork to Solve Environmental Problems

Skills and expertise of multiple disciplines used to address complex engineering problems as a team

Outcome Explanation: The solutions of most engineering problems require the expertise and participation of a variety of disciplines. The environmental engineer will use management and communication skills to create, manage, and/or participate in teams composed of professionals from a broad range of disciplines. This requires understanding team formation and evolution, individual characteristics, team dynamics, collaboration among diverse disciplines, problem solving, time management and an ability to foster and integrate diversity of perspectives, knowledge, and experiences (ASCE, 2008).

Baccalaureate Level:

- **Identify** disciplines necessary to solve a complex environmental engineering problem. (C1, A3)
- **Describe** the characteristics of an effective team. (C2, A3)
- **Function** in an environmental engineering team to design and implement solutions. (C3, A3)

After Professional Experience:

- **Function** effectively in multi-disciplinary team activities. (C3, A4/A5)

Outcome 13: Professional and Ethical Responsibilities

Professional and ethical issues in environmental engineering

Outcome Explanation: Whereas morals are values relating to how humans ought to treat each other, ethics are rules for how humans ought to treat each other in the absence of detailed moral values or when moral values conflict. Moral behavior, in both personal and professional matters, is expected of all environmental engineers. Professional ethics for engineers is spelled out in the various codes of ethics such as those adopted by ASCE, NSPE, and AIChE. Often these codes provide guidance on how moral dilemmas can be honorably resolved, but sometimes the engineer is asked to make morally-significant decisions that do not have simple or straightforward resolutions. Ethical decision-making is thus a useful and required skill for all professional engineers.

In environmental engineering, professional ethics is complicated by the responsibility engineers have for preserving our natural environment. Natural ecosystems support human existence, and thus service to the public must include the preservation of species and habitats. In addition, environmental engineers recognize that all of nature has intrinsic value and that preventing the despoilment and destruction of the natural environment is part of their professional responsibility.

Baccalaureate Level:

- **Recognize** moral and ethical problems that might arise in engineering practice. (C1, A2)
- **Explain** tenets of professionalism and codes of engineering ethics. (C2, A2)
- **Apply** standards of professionalism and codes of engineering ethics to determine an appropriate course of action for a given environmental engineering situation. (C3, A2)

M/30 Level:

- **Analyze** an environmental engineering situation involving conflicting ethical and professional interests to determine an appropriate course of action. (C4, A4)

After Professional Experience:

- **Describe** a situation based on personal experience with environmental engineering situations and course of action that illustrates professional and ethical behavior. (C5, A5)
- **Assess** personal professionalism and ethical development. (C6, A5)

Outcome 14: Effective Communication

Effective communications when interacting with the public and the technical community

Outcome Explanation: The environmental engineer is frequently the critical link to public understanding and interpretation of environmental policy, issues, and implementation of plans for projects that affect public health and the environment. The environmental engineer must communicate using verbal, written, virtual, and graphical means to describe a concept, an environmental degradation or enhancement issue, and / or a project affecting the environment to technical and non-technical audiences, and receive and interpret communications in return.

Baccalaureate Level:

- **Describe** the characteristics of effective verbal, written, virtual and graphical communications. (C2, A3)
- **Apply** the rules of grammar and composition in verbal and written communications, properly cite sources. (C3, A3)
- **Use** appropriate graphical standards in preparing engineering documents and presentations. (C3, A3)
- **Summarize** the essential points and elements of verbal and written communications received from others. (C4, A3)
- **Organize** and deliver effective verbal, written, virtual, and graphical communications. (C5, A3)

M/30 Level:

- **Make** effective presentations to technical audiences. (C3, A3)
- **Interpret** the intent and content of communications from technical and non-technical stakeholders in a concept or project. (C4, A4)
- **Plan**, **compose**, and **integrate** the verbal, written, virtual and graphical communication of a concept or project to technical and non-technical audiences. (C5, A4)
- **Communicate** the concept of uncertainty and risk to technical and non-technical audiences. (C5, A4)
- **Develop** conclusions that logically follow from data results and discussion. (C5, A4)

After Professional Experience:

- **Make** effective presentations to technical and non-technical audiences. (C3, A3)
- **Evaluate** the effectiveness of the integrated verbal, written virtual and graphical communication of a concept or a project to technical and non-technical audiences. (C6, A5)
- **Evaluate** the accuracy of interpretations of communications from technical and non-technical stakeholders in a concept or project. (C6, A5)

Outcome 15: Lifelong Learning

Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns

Outcome Explanation: Environmental engineering is an ever-developing profession, where environmental concerns multiply with additional complexity of society, and with the development and use of more complex materials that are frequently toxic or otherwise disruptive to the environment and to public health, welfare and safety. Demand for efficiency in processes, including processes for environmental risk management, requires awareness of impacts and developing technology; accordingly, life-long learning is essential to environmental engineering.

Baccalaureate Level:

- **Define** life-long learning. (C1, A3)
- **Explain** the need for life-long learning. (C2, A3)
- **Describe** the skills required of a life-long learner. (C2, A3)
- **Demonstrate** the ability for self-directed learning. (C3, A2)

M/30 Level:

- **Identify** additional knowledge, skills and attitudes appropriate for continued practice at the professional level. (C4, A3)
- **Integrate** self-directed learning of issues that apply to environmental engineering. (C5, A4)

After Professional Experience:

- **Plan** a regimen of continued learning to maintain proficiency. (C5, A5)
- Regularly **acquire** additional expertise and **maintain** skills and appropriate current knowledge. (C6, A5)

Outcome 16: Project Management

Principles of project management relevant to environmental engineering

Outcome Explanation: Project Management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing (Project Management Institute 2004, *A Guide to the Project Management Body of Knowledge – Third Edition*, Newtown Square). Meeting project budget, scope, and schedule are the primary goals of project management.

Baccalaureate Level:

- **List and explain** project management processes and principles. (C1/C2, A2)
- **Explain** how project management and construction relate to the project delivery process. (C2, A2)
- **Solve** well defined project management problems. (C3, A2)

M/30 Level:

- **Apply** project management to a project. (C3, A3)

After Professional Experience:

- **Create** documents to be incorporated into a project management plan as a member of an engineering team. (C5, A5)
- **Create** to project management plans as a member of an engineering team. (C5, A5)

Outcome 17: Business and Public Administration

Business knowledge and communication skills for administration of both private and public organizations

Outcome Explanation: Environmental engineers typically deal with both private and public organizations, and they must understand business fundamentals such as organizational structure, income statements and balance sheets as well as public administration fundamentals such as the political process, regulations, asset management and funding processes. Asset management is a business process and a decision making framework that covers an extended time, and draws from both economics and engineering. Many environmental engineers use asset management principles in managing and maintaining environmental infrastructure.

Baccalaureate Level:

- **List and describe** important fundamentals of business and of public administration related to environmental engineering. (C1/C2, A2)

After Professional Experience:

- **Analyze** problems involving business and public administration as they relate to environmental problems. (C4, A4)

Outcome 18: Leadership

Engaging, motivating and leadership of others to achieve common vision, mission and goals

Outcome Explanation: Leadership is the art and science of influencing others toward achieving common goals (ASCE, 2008). Leadership abilities are important for success in all professional endeavors, and especially where teamwork is involved. Because many environmental engineering projects require that several individuals work collectively toward common goals, leadership abilities are critical for the environmental engineer. Leadership requires technical competence, continuous self-improvement, timely and responsible decision making, self-confidence effective communication, and moral behavior. Attributes of leaders include vision, enthusiasm, energy, commitment, selflessness, discipline, confidence, communication skills, and persistence. These abilities and attributes can be taught and developed in both formal education and engineering practice (ASCE, 2008). Examples of opportunities to develop leadership within the educational setting include leading design teams, team competitions, student organizations, and athletic teams. Leadership should be further developed during the professional career in real-world settings. Senior engineers should mentor junior engineers and provide opportunities for leadership.

Baccalaureate Level:

- **Define** leadership and the role of a leader. (C1, A2)
- **List** leadership skills and attributes. (C1, A2)
- **Explain** the role of a leader, leadership skills, and leadership attributes. (C2, A2)
- **Apply** leadership skills to direct the efforts of a small group. (C3, A2)

After Professional Experience:

- **Organize** and **direct** the efforts of a group to achieve a goal. (C3, A2)