AC 2008-175: DEVELOPING A BODY OF KNOWLEDGE FOR ENVIRONMENTAL ENGINEERING

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Developing a Body of Knowledge for Environmental Engineering

Introduction

At the American Academy of Environmental Engineers (AAEE) Board of Trustees annual meeting in November 2005, a Body of Knowledge Development Working Group (BOKDWG) was created with the following charge:

> "The Body of Knowledge Development Working Group is charged with defining the BOK needed to enter the practice of environmental engineering at the professional level in the 21st century taking into account other issues, including, but not limited to, the impact on certification, on the profession, on environmental engineering academic programs (undergraduate and graduate), and on accreditation of environmental engineering programs at the basic and advanced levels."

A body of knowledge (BOK) provides the foundations that define a profession. The need for a BOK that aligns engineering curricula and early experiences with the professional demands of engineers has been recognized by many engineering disciplines in recent years. The American Society of Civil Engineers (ASCE) recently published its second edition of a Civil Engineering BOK (ASCE 2008). The National Academy of Engineering's Committee on Engineering Education considered the future of undergraduate engineering education in the United States (NAE 2005). The study was not limited to one or two disciplines of engineering but rather to all the diverse branches of engineering and from the broadest perspective. The Committee identified the need for a BOK that ensured the preparation of engineers for the demands the field will place upon engineers in a global economy.

The EnVE BOKDWG was populated by a diverse body of environmental engineers representing multiple employment areas and experience levels. While this effort was initiated by the AAEE, it is by no means exclusively an AAEE activity. The Environmental Engineering Body of Knowledge (EnVEBOK) is being developed through a series of teleconferences and face-to-face meetings. Stakeholder opinion will be collected through communication with groups with EnVEBOK interests through wide distribution of early drafts and updates at conferences and newsletters.

Face-to-face meetings are an important part of the EnVEBOK development effort. They provide an opportunity to focus on this effort without distraction for a longer period of time than teleconferences permit and to generate interactive discussion that is not possible by telephone. The first face-to-face meeting of the EnVEBOK working group was help in Tempe, AZ at the NSF-funded Foundations of Environmental Engineering Education meeting. A second meeting was held at Virginia Tech at the 2007 AEESP Research and Education Conference July 29, 2007 and the third face-to-face meeting was held on February 1, 2008 in Orlando, FL.

Structure of the Environmental Engineering Body of Knowledge

The Environmental Engineering BOK describes the knowledge and core competencies integral to the understanding and practice of environmental engineering. Acquiring the EnVEBOK could lead to environmental engineering licensure and certification. However, the EnVEBOK DWG did not assume that every environmental engineering student receiving a baccalaureate degree continues on to receive a Masters in environmental engineering. Nor did it assume that practice of environmental engineering always results in licensure. The practice of environmental engineering includes, but is not limited to planning, design, teaching, applied or fundamental research, public administration, or utility operation and the EnVEBOK must address all these forms of practice. Individuals receiving a degree in environmental engineering may never practice environmental engineering, but rather may seek other professional degrees, such as law or medicine, or follow an entirely different career path. Therefore some paths beginning with a baccalaureate degree in environmental engineering may not lead to complete EnVEBOK fulfillment.

The EnVEBOK builds on the body of knowledge appropriate for all engineers then expands into areas specific and unique to environmental engineering. The EnVEBOK provides a guide for curriculum development and reform, a means for employers to better understand the knowledge base of environmental engineers, and a mechanism to identify specific desirable attributes of environmental engineers. The EnVEBOK is not overly prescriptive and is outcomes-based. The EnVEBOK will help educators to design curricula that provide the basis to gain the competencies for professional practice. The EnVEBOK is defined by outcomes largely based on ABET 2000 Criteria, but placed in the context of environmental engineering. Within the defined outcomes, core competencies, knowledge domains, and performance levels achieved are identified, defined as follows:

- An **Outcome** states or describes an ability to perform a task,
- A **Knowledge Domain** is an organized field of human cognition such as history or mathematics.
- A **Performance Level** defines the scholarly depth of the task.

Core competencies have been defined in outcomes and required knowledge areas are identified for each outcome.

Outcomes

The Environmental Engineering BOK Outcomes have been arranged in three groups (see 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.

The second group identifies outcomes essential to the problem-solving process that involves defining the problem, identifying constraints and alternative solutions, analyzing the solutions, solution optimization, and selecting and implementing the appropriate solution. The process is cyclical, requiring problem redefinition and refining as information is acquired followed by verification of results after the solution is implemented. Problem solving involves both

Table 1. List of Environmental Engineering BOK Outcomes

Outcome Number and Title
Fundamental Outcome
1. Basic Environmental Math & Science (BEMS) Knowledge
Enabling Knowledge and Skills Outcomes
2. Design and Conduct Experiments
3. Modern Engineering Tools
4. In-Depth Competence
5. Risk, Reliability and Uncertainty
6. Problem Formulation and Conceptual Analysis
7. Creative Design
8. Sustainability
9. Multimedia Breadth and Interactions
10. Societal Impact
11. Contemporary and Global Issues
Professional Outcomes
12. Multi-disciplinary Teamwork
13. Professional and Ethical Responsibilities
14. Effective Communication
15. Lifelong Learning
16. Project Management
17. Business, Public Administration, and Environmental Policy
18. Leadership

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 and societal and global needs. 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 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 career, they must remain cognizant of changing technology and issues. Public confidence in these solutions requires that environmental engineers conduct themselves ethically. The public must appreciate the role environmental engineers may play as leaders of the profession and in society, for example, when the solutions to environmental engineering issues they recommend require policy changes.

More details regarding the EnVEBOK outcomes can be found at www.cecs.ucf.edu/BOK.

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 they may be topics within multiple courses taught at different levels. Figure 1 provides a rubric with knowledge domains identified and mapped to the 18 outcomes. More details can be found at www.cecs.ucf.edu/BOK.

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 EnVEBOK fulfillment at each of these points is described using terminology that characterizes the outcome performance in terms of its cognitive rigor and practical relevance.

Conclusions

The purpose of the EnVEBody of Knowledge is to provide a guide for curriculum development and reform, a guide for employers so they know what they are getting when they hire an environmental engineer, and a mechanism to call for specific attributes such as creativity and innovation. The EnVEBOK is a compass for educating the environmental engineer that must provide flexibility without prescribing a set curriculum. It must serve all stakeholders - the profession, the academe, students, and society. The EnVEBOK reflects our profession's responsibility to address societal challenges with intelligent and practical solutions. It will help to prepare students for an unknown future; to have the skills necessary to learn and apply principles to new problems and make the most of new opportunities.

Input from stakeholders is essential to a successful EnVEBOK. Throughout 2008, the Task Force will be seeking input through various means including the EnVEBOK website (www.cecs.ucf.edu/BOK), presentations, emailings, and publication of articles.

The development of the EnVEBOK is a continuous process of testing and improvement.

As it is implemented, practitioners and educators must evaluate the EnVEBOK and determine whether all issues necessary to the practice of environmental engineering have been addressed, 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 EnVEBOK to ensure that engineers will be trained 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 to evaluate whether curricula can be reasonably designed to adopt the EnVEBOK. Educators should also determine whether the levels of achievement are correctly defined. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the EnVEBOK should be used with respect to accreditation, licensing, and promotion of the profession.

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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																		

Figure 1. Matrix of Outcomes and Knowledge Domains