COMMENTARY

On the ABET Program Criteria for

Environmental Engineering Programs

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Preamble to Commentary

This Commentary is intended to provide program evaluators with guidance in interpreting the Environmental Engineering Program Criteria. Environmental engineering programs can meet these criteria in a variety of ways and this document is intended to provide only general guidance. Program evaluators should use professional judgement is assessing whether elements within the program criteria are met, within the context of these guidelines.

Although this Commentary is primarily intended to address the interpretation of the Environmental Engineering Program Criteria, there are some aspects of the General Criteria that relate to the program criteria. These are discussed below.

Criterion 3. Student Outcomes

ABET/EAC program criteria are curriculum and faculty requirements; they are not student outcomes. As such, programs are under no obligation to establish additional program-criteria-related student outcomes beyond those explicitly required by Criterion 3. If a program chooses to establish additional program-criteria-related student outcomes, then the program will need to assess the additional student outcomes.

Criterion 5. Curriculum

This criterion requires that "students be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating appropriate engineering standards and multiple realistic constraints." If an environmental engineering program has a common major design experience with a other programs, for example, civil engineering, or environmental engineering students are participants in a multidisciplinary design project, the program evaluator should ensure that environmental engineering students are assigned design tasks that are based on environmental engineering coursework in their curriculum. Also, to ensure the quality of the environmental engineering major design experience, the environmental engineering design experience should be evaluated by a faculty member or project supervisor that is qualified in the area of the design. If the major design experience of environmental engineering students is not in a specialty area of environmental engineering, then this could be a shortcoming because students in the environmental engineering program are not being adequately prepared for the practice of environmental engineering through the major design experience.

Program evaluators should be careful not to enforce additional requirements for the major design experience that are not stated in Criterion 5. For example, the criterion does not require that drawings and cost estimates be part of the major design experience.

ABET/EAC Environmental Engineering Program Criteria

1. Curriculum

The curriculum must prepare graduates to apply knowledge of mathematics through differential equations, probability and statistics, calculus-based physics, chemistry (including stoichiometry, equilibrium, and kinetics), an earth science, a biological science, and fluid mechanics. The curriculum must prepare graduates to formulate material and energy balances, and analyze the fate and transport of substances in and between air, water, and soil phases; conduct laboratory experiments, and analyze and interpret the resulting data in more than one major environmental engineering focus area, e.g., air, water, land, environmental health; design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts; and apply advanced principles and practice relevant to the program objectives. The curriculum must prepare graduates to understand concepts of professional practice, project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulations.

2. Faculty

The program must demonstrate that a majority of those faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, board certification in environmental engineering, or by education and equivalent design experience.

1. Curriculum

The curriculum must prepare graduates to apply knowledge of mathematics through differential equations, probability and statistics…

Preparation of graduates to apply knowledge of mathematics through differential equations is usually accomplished by mandatory calculus courses in the curriculum. These calculus courses typically cover the principles and applications of differentiation and integration, vectors and vector-valued functions, and multivariable and vector calculus. Coverage of differential equations typically includes ordinary and partial differential equations and their corresponding solution techniques. Probability and statistics are separate but related areas of study. Probability theory is used to quantify the likelihood that a single event or combination of events will occur, whereas statistics are used to quantify the characteristics of data or the relationships between data sets. Preparation of program graduates to apply knowledge of probability and statistics can be accomplished by having a mandatory course in probability and statistics, or integrating substantial coverage of probability and statistics into one or more mandatory engineering courses. The curriculum should demonstrate the application of probability and statistics to environmental engineering.

The curriculum must prepare graduates to apply knowledge of calculus-based physics

The requirement for calculus-based physics means the curriculum should include at least one physics course that requires calculus as a prerequisite. Alternatively, the curriculum could require a physics course in which differentiation and integration are taught and are used to derive basic physical relationships. This criterion requires that students be able to "**apply** knowledge" of calculus-based physics, which means that students should be able to solve problems using the material learned in their physics course(s).

The curriculum must prepare graduates to apply knowledge of chemistry (including stoichiometry, equilibrium, and kinetics)

The program must demonstrate that the curriculum teaches the basic principles of chemistry and prepares program graduates to apply these basic principles. Chemistry coverage would normally include at least one course in general chemistry, and coverage must include the basic principles of stoichiometry, equilibrium, and kinetics. This criterion requires that students be able to "**apply** knowledge" of chemistry, which means that students should be able to solve problems using the material learned in their chemistry course(s).

The curriculum must prepare graduates to apply knowledge of an earth science

Preparation of graduates to "apply knowledge" implies an ability to apply basic concepts, principles and theories. This criterion requires that program graduates have sufficiently advanced knowledge of an earth science that they can apply this earth-science knowledge in novel environmental engineering applications. This criterion is usually met by a curriculum that includes at least one required earth science course. If a separate earth science course is not required, then this criterion can be met by having in-depth earth science coverage within one or more courses that also cover other topics. Earth sciences include but are not limited to the disciplines of geology, soil science, hydrologic science, meteorology, oceanography and limnology. The emphasis of an earth science is on basic science rather than engineering, and therefore courses such as geotechnical engineering, soil mechanics, and engineering hydrology would not normally have sufficient earth-science coverage to meet this criterion.

The curriculum must prepare graduates to apply knowledge of a biological science

This criterion is usually met by a curriculum that includes at least one required course in biology, such as general biology or microbiology, or in a closely related area such as ecology or toxicology. If a separate biological science course is not required, then this criterion can be met by having in-depth biological science coverage within one or more courses that also cover other topics. Biological science is the study of living things, and the emphasis of this criterion is on basic science rather than engineering. Courses such as water and wastewater engineering, wastewater treatment, and unit processes would not normally have sufficient biological science coverage to meet this criterion.

The curriculum must prepare graduates to apply knowledge of fluid mechanics

This criterion is usually met by a curriculum that includes at least one required course in fluid mechanics. If a separate fluid mechanics course is not required, then this criterion can be met by having in-depth fluid mechanics coverage within one or more courses that also cover other topics. Fluid mechanics is an engineering science, and the emphasis of this criterion is on scientific principles rather than engineering. Courses in open-channel flow and hydrology would not normally have sufficient fluid mechanics coverage to meet this criterion. Essential topics that are normally covered in the area of fluid mechanics include the principles of fluid statics and the dynamics of fluids under laminar and turbulent flow conditions.

The curriculum must prepare graduates to formulate material and energy balances

Material balances are based on the law of conservation of mass, and energy balances are based on the law of conservation of energy, which is sometimes called the first law of thermodynamics. Coverage of material and energy balances can be either in a single course or distributed within several courses. Formulation of material and energy balances can be done using either control-volume or differential-analysis approaches. This criterion requires that students be able to "**formulate**" material end energy balances, which means that students should be able to synthesize information and develop novel solutions using material and energy balances. It would normally be expected that such formulations would be in environmental-engineering contexts.

The curriculum must prepare graduates to analyze the fate and transport of substances in and between air, water, and soil phases

"Fate" processes include physical, chemical, and biological transformations of substances, and "transport" processes include diffusion, dispersion, advection, interphase mass transport, and settling processes associated with the physical movement of substances present as atoms, molecules, or particulate phases. Fate and transport processes occur in all states of matter, and the criterion specifically requires that the curriculum contain coursework in the fate and transport of substances in and between air, water, and soil phases. The curriculum should include, as a minimum, coverage of interphase chemical equilibrium and the formulation and application of the advection-diffusion equation for non-conservative substances, with specific applications in environmental engineering. Topics covered should be in sufficient detail to provide program graduates with analysis capability, and the topics covered can vary by program. Examples of topics that are relevant to environmental engineering include: mass transport across phase boundaries, models of biologically mediated decay, fate of pathogens in the environment, nutrient-biomass relationships, and the fate of nonaqueous phase liquids in soil and groundwater.

The curriculum must prepare graduates to conduct laboratory experiments, and analyze and interpret the resulting data in more than one major environmental engineering focus area, e.g., air, water, land, environmental health

This criterion is an extension of General Criterion 3(b) which requires "an ability to design and conduct experiments, as well as to analyze and interpret data". Within Environmental Engineering, the emphasis is on conducting laboratory experiments utilized in characterization, monitoring, process analysis or pilot plant studies and then analyzing and interpreting the resulting data. Compliance with this Program Criterion is usually demonstrated by showing that all program graduates have sufficient exposure to laboratory experiences within the curriculum that relate to processes in at least two different mediums (solid, liquid, gas). Care should be taken to discern between laboratory experiments relating to the solid, liquid, and gas media. For example, gravimetric analysis of solids content, determination of concentrations of indicator organisms, and determination of both the solubility and the concentration of oxygen in water (or any other liquid) all relate to the water (or liquid) medium. The aforementioned laboratory experiences are basically all water-quality analyses. Laboratory experiences in environmental health would also be appropriate as a separate focus area if the curriculum provides an exposure to topics such as environmental toxicology, pathogen and/or indicator-organism quantification, and industrial hygiene. Laboratory training relating to safety and hygiene is not a requirement of the program criteria, such training is related to the APPM laboratory safety requirement.

Design is an iterative, creative decision-making process of devising an environmental engineering system to meet desired needs, specifications, codes, and standards within constraints. The breadth of design experiences across the curriculum should reflect the breadth of the environmental engineering discipline (air, water, land), however, there are no requirements for the design to be applied to any specific medium. The design constraints must include a minimum

The curriculum must prepare graduates to design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts

of the following five considerations: risk, uncertainty, sustainability, life-cycle principles, and environmental impacts, although other constraints may be included. Although applications and contexts can be quite variable, consideration of risk is usually expressed in terms of probability of failure of a system, uncertainty is usually expressed in terms of a range of possible outcomes of an event or variable, life-cycle principles usually relate to quantifying the environmental impacts of the manufacture, use, maintenance, and final disposal of a material or product, and environmental impacts usually relate to quantifying or describing alterations of the natural environment resulting from a given activity.

The curriculum must prepare graduates to apply advanced principles and practice relevant to the program objectives

The program must demonstrate that coursework in environmental engineering topics is advanced beyond introductory-level coverage in one or more of the recognized specialty areas of environmental engineering. Student abilities relating to advanced principles and practice are at the “apply” level as defined by Blooms taxonomy, and coverage of environmental engineering topics are consistent with the program’s educational objectives. The “apply” level of cognitive ability infers a capability to solve problems by applying acquired knowledge, facts, techniques, and rules in creative ways. The advanced coursework must support achievement of the program’s educational objectives. For example, if a program’s education objectives include graduates excelling in engineering practice, then the curriculum should include sufficiently advanced courses emphasizing the practice of environmental engineering for graduates to qualify for entry-level engineering positions. As another example, if the program’s education objectives include having graduates successfully complete advanced studies in environmental engineering, then the program should demonstrate that students take advanced coursework expected of entry-level students at either the MS or PhD level. The distribution of emphasis on engineering analysis versus design is at the discretion of the program in meetings its educational objectives.

The curriculum must prepare graduates to understand concepts of professional practice, project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulations

Elements within this criterion can be covered either in a single course or in multiple courses across the curriculum. Environmental engineers are professionally engaged across a wide spectrum of business, governmental, and non-profit organizations with a common acceptance of standards of practice including ethical responsibilities. Coverage of concepts of professional practice usually includes such topics as engineering economics, professional ethics, and engineer-client-stakeholder relationships. Project management usually includes coverage of the roles and responsibilities of various parties within a project; topics related to project management are sometimes covered and practiced within team-based exercises such as design projects. Program graduates are expected to be familiar with the roles and responsibilities of the various public institutions responsible for setting environmental policies, passing laws, developing regulations, and enforcing those regulations through permits. Program graduates are also expected to be familiar with the roles and responsibilities of private organizations to comply with applicable environmental regulations, and to shape public policy. Program graduates should be generally aware of their professional mandate to protect the public trust regardless of the employment sector.

2. Faculty

Majority of faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, board certification in environmental engineering, or by education and equivalent design experience.

The requirement of professional licensure is generally met by registration as a Professional Engineer within the United States. Equivalent professional registration obtained in other countries can also meet the requirement of professional licensure, and the program evaluator will need to make a judgement as to equivalence of registration standards. The discipline in which a faculty member is registered and the practice area of the faculty member should be closely aligned with the course(s) being taught. Board certification in environmental engineering is normally met via BCEE certification by the American Academy of Environmental Engineers and Scientists (AAEES). Other AAEES certifications such as BCEEM and BCES are not generally associated with design experience, and therefore the design qualifications of faculty members with these certifications should be reviewed in more detail. The ASCE certification Diplomate Water Resources Engineer (D.WRE) is an acceptable qualification for faculty members teaching design courses. In the absence of acceptable credentials, such as P.E., BCEE, or D.WRE, qualification by virtue of education and equivalent design experience usually requires that the instructor have both the appropriate academic training and satisfy the minimum design experience required to become a licensed professional engineer.