

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 in assessing whether the requirements of 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.

Program evaluators are encouraged to review summer and intersession offerings of required and elective courses to verify that both the material covered and the attainment of student outcomes in these courses are consistent with those of the same courses offered in regular semesters.

Criterion 5. Curriculum

Criterion 5(a)

This criterion states that “a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.” The EAC Criteria document defines basic sciences as “disciplines focused on knowledge or understanding of the fundamental aspects of natural phenomena. Basic sciences consist of chemistry and physics and other natural sciences including life, earth, and space sciences.” Coursework in Geographic Information Systems (GIS) usually does not meet the definition of a basic science.

Criterion 5(d)

This criterion states that “The curriculum must include a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.” If an environmental engineering program has a common major design experience with 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 the knowledge and skills acquired in their environmental engineering coursework. Therefore, the focus of the culminating major design experience for environmental engineering students should not be in external areas such as structural or transportation engineering, as might occur in joint environmental-civil engineering capstone courses. 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 Criterion 5 states that “The program curriculum must provide adequate content for each area, consistent with the student outcomes and program educational objectives, to ensure that students are prepared to enter the practice of engineering.” If the major design experience is not in a specialty area of environmental engineering, then students are not being adequately prepared for the practice of environmental engineering.

The design of a field sampling system for collecting environmental data is usually not considered as environmental engineering design.

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 who is qualified in the area of the design. Aside from the quality issue, lack of qualified environmental engineering supervision in the culminating design experience could also be cited as a shortcoming in Criterion 6, which requires that the program must demonstrate that the faculty members “have the competencies to cover all of the curricular areas of the program.”

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.

Environmental Engineering Program Criteria

The program criteria are divided into two sections: curriculum and faculty. The curriculum requirements specify topics that must be substantially covered in the required coursework of the environmental engineering program. Verification that a program meets the curriculum requirements can be done by reviewing the curriculum, course syllabi, and sample coursework; along with interviews with faculty members and students. The faculty requirements of the program criteria relate only to the qualifications of faculty members teaching design courses. Verification that a program meets the faculty requirements can be done by identifying the required design courses in the curriculum, and reviewing the qualifications of the faculty members who teach these courses. More detailed guidance on evaluating compliance with the program criteria is provided in this document.

ABET/EAC Environmental Engineering Program Criteria

1. Curriculum

The curriculum must include:

- a) Mathematics through differential equations, probability and statistics, calculus-based physics, chemistry (including stoichiometry, equilibrium, and kinetics), earth science, biological science, and fluid mechanics.
- b) Material and energy balances, fate and transport of substances in and between air, water, and soil phases; and advanced principles and practices relevant to the program objectives.
- c) Hands-on laboratory experiments, and analysis and interpretation of the resulting data in more than one major environmental engineering focus area, e.g., air, water, land, environmental health.
- d) Design of environmental engineering systems that includes considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts.
- e) Concepts of professional practice and 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 members 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

a) Mathematics through differential equations, probability and statistics, calculus-based physics, chemistry (including stoichiometry, equilibrium, and kinetics), earth science, biological science, and fluid mechanics.

Mathematics through differential equations

Mathematics coursework should include calculus, which is the basis of differential equations. Calculus coursework typically covers 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

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. Coverage of probability and statistics can be accomplished by having a mandatory course in probability and statistics, or by integrating substantial coverage of probability and statistics into one or more mandatory engineering courses.

Calculus-based physics

The curriculum could include at least one physics course that requires calculus as a prerequisite, or the curriculum could require a physics course in which differentiation and integration are taught within the course and are used to derive basic physical relationships.

Chemistry (including stoichiometry, equilibrium, and kinetics)

Chemistry coverage would normally include at least one course in general chemistry, and topics must include the basic principles of stoichiometry, equilibrium, and kinetics.

Earth science

This criterion is usually met by a curriculum that requires at least one 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 required courses that 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.

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 a course 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 required 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.

Fluid mechanics

This criterion is usually met by requiring at least one 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 required courses that 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.

b) Material and energy balances, fate and transport of substances in and between air, water, and soil phases; and advanced principles and practices relevant to the program objectives.

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.

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. Examples of fate and transport 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.

Advanced principles and practices 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. Advanced principles are normally those principles taught in a second course in a subject area. 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 could 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 could 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 meeting its educational objectives.

c) Hands-on laboratory experiments, and analysis and interpretation of 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(6) which requires "an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions". 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 exposure to hands-on laboratory experiences within the curriculum that relate to processes in at least two different environmental engineering focus areas. Relevant environmental engineering focus areas are: air pollution control, solid and hazardous waste management, industrial hygiene, and water supply/wastewater. The "hands-on" requirement of this criterion normally precludes virtual labs; however, under unusual circumstances, such as a pandemic or local disaster, virtual labs might

be necessary and acceptable. Care should be taken to discern between laboratory experiments relating to the different environmental engineering focus areas. 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 all relate to water. The aforementioned laboratory experiences are basically all water-quality analyses. Laboratory experiences in environmental health could also be appropriate as a separate focus area if the curriculum provides laboratory experiences in 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.

Surveying exercises are not to be considered as laboratory experiments in environmental engineering curricula.

d) Design of environmental engineering systems that includes considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts.

The General Criteria provides a detailed definition of engineering design. The ABET definition of engineering design is given below for ready reference:

Engineering design is a process of devising a system, component, or process to meet desired needs and specifications within constraints. It is an iterative, creative, decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions. Engineering design involves identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making tradeoffs, for the purpose of obtaining a high-quality solution under the given circumstances.

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 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 either in terms of health risk, ecological risk, or 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; sustainability relates to practices that support ecological, human, and economic health while meeting the needs of the present and not compromising the ability of future generations to meet their needs; 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.

e) Concepts of professional practice and project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulations.

The five considerations stated in this criterion do not have to be covered in a single course, such as the capstone design course, they could be covered across many environmental engineering courses. Coverage of these topics does not have to be extensive.

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. 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. Relevant curricula topics include: the roles and responsibilities of the various public institutions responsible for setting environmental policies, passing laws, developing regulations, and enforcing those regulations through permits; the roles and responsibilities of private organizations to comply with applicable environmental regulations, and to shape public policy; and the mandate of professional engineers to protect the public trust regardless of the employment sector.

2. Faculty

A majority of those faculty members 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 program normally identifies courses that are primarily design, and the credentials of the faculty members teaching these design courses are evaluated. The program evaluator should also review the content of all required engineering courses to ensure that all design courses have

been identified. Qualifications of faculty teaching elective design courses are not considered under this criterion.

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. In some countries, registration as a professional engineer simply requires having a degree in engineering, with no experience requirement; this would not be equivalent to professional licensure as understood in the United States. 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 do not require 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.