Recommendations for Liberal Education in Engineering: A White Paper from the Liberal Education Division of the American Society for Engineering Education

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I. Introduction: The Origins and Purpose of the White Paper

This White Paper offers recommendations for liberal education (LE) in engineering education in response to the opportunities presented and needs highlighted by ABET's *Criteria 2000*. The first version of the White Paper was created under the leadership of Nicholas Steneck and Barbara Olds and presented at the 2001 meeting of ASEE. The interest generated by that presentation confirmed that general guidelines of the type the White Paper presents were both needed and welcomed by the engineering education community.

Following the 2001 meeting, Kathryn Neeley, outgoing chair of the Liberal Education Division, joined Steneck and Olds in the effort to bring the White Paper to completion and to the attention of the various parties who will be involved in the implementation of *Criteria 2000*. The text that follows has been amended and expanded by Steneck, Olds, and Neeley based on the feedback received at the 2001 meeting and subsequent to it.

The discussions that led to the development of this White Paper suggest that it is probably not possible and perhaps even not desirable to seek unanimity on the definition of LE or the ideals that should guide it. The intent here is to provide general guidelines and broad standards for the engineering education community to use in implementing ABET's *Criteria 2000*.

II. *Criteria 2000*: An Opportunity to Define and Strengthen the Role of Liberal Education

Criteria 2000 provides opportunities for more clearly defining and strengthening the role of liberal education in engineering. Liberal education can contribute significantly to the development of all of the program outcomes defined by ABET and is essential to seven of them:

(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems[1]
(f) an understanding of professional and ethical responsibility

[1] With regard to outcome (e), LE is particularly useful for developing the ability to reflect on and think critically about the process of problem definition.

(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues

Liberal education is also directly relevant to ABET's requirement that students be prepared to deal with “economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political" issues when they finish their final design course and prepare to enter practice (*Criteria 2000)*. Accordingly, it can reasonably be concluded that a commitment to LE is essential for meeting ABET's new standards and assessment procedures.

Criteria 2000 does not, however, specify how the new requirements should be met. Instead, it is left up to each school or program a) to define its learning objectives, b) to develop ways to assess whether its objectives are being met, and c) to revise its curriculum in response to assessment outcomes to ensure ongoing educational improvement. Although engineering educators and accreditors have long recognized the value of liberal education as a component of engineering education, most do not have expertise in the disciplines comprising liberal education and may have difficulty envisioning how liberal education should be designed and assessed under *Criteria 2000.*

With this White Paper, the Liberal Education Division of ASEE seeks to provide recommendations for defining and assessing liberal education in engineering, focusing first on clarifying the definition and goals of liberal education and then providing guidelines for implementing and assessing the liberal education requirements set out in *Criteria 2000*. While intended specifically for use by schools and programs that are preparing for an ABET review, the materials presented in this White Paper are designed to be broadly applicable to any discussion of the role of liberal education in engineering. We also intend as an organization within engineering to work to produce specific resource materials that will help schools and programs translate general guidelines and objectives into an exciting course of study.

III. General Purpose of Liberal Education in Engineering

Liberal education encompasses broad learning objectives *and* specific learning skills, taught through a broad range of courses generally grouped under the humanities (including the arts) and social sciences (H&SS). It is important to note that the goals of LE are not limited to the competencies prescribed by *Criteria 2000* and detailed in this White Paper. Liberal education for engineering students is just one aspect of a much larger educational enterprise whose goals have been debated for centuries and whose purposes go beyond those discussed here.

In the context of engineering education, LE broadens students' perspectives and helps them develop as individuals and members of a broader society outside of their profession. Study in nontechnical disciplines also gives students a better understanding of the society in which their technical products will be used. By providing specific instruction on topics such as communication, ethics, and science studies (also called STS or "science, technology and society" studies), LE imparts information and skills that are essential for the responsible practice of engineering. The technical components of an engineering education provide skills that are used to formulate, analyze, and solve technological problems. LE helps students develop the character, understandings, and skills needed to formulate, analyze, and solve technological problems in a thoughtful, responsible way, within the context of society's structures and mores.

IV. Curriculum Design and Learning Objectives for Liberal Education in Engineering Education

Curriculum Design

As an area of study that encourages self-discovery, the exploration of different ways of thinking, and broad intellectual development, LE in engineering cannot be reduced to a single course of study. No single pattern of learning is right for every student, teacher, program, or school. In fact, LE can be delivered in many ways, including:

> *Traditional H&SS Courses*. Courses entirely devoted to some aspect of a humanities or social science discipline and taught by experts in the discipline. These courses provide the opportunity for immersion in the intellectual perspectives and culture of other disciplines and help students develop appreciation for the nature of expertise in fields other than their own.
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> *Integrated Modules*. Courses taught by experts in science/engineering disciplines into which units or modules dealing with areas such as communication, ethics, or teamwork are integrated. Collaboration with experts in the LE topic in question strengthens the design of such courses.
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> *Interdisciplinary courses*. Courses that focus on important intersections of engineering practice with the humanities and social sciences, such as engineering ethics and technical communication. These are taught by humanities and social science faculty familiar with various aspects of science, technology, and engineering or team taught by H&SS and engineering/medical/science faculty.

All three modes of instruction offer distinct advantages, and they contribute in different ways to achieving the objectives outlined below. While we realize that not every program will be able to incorporate all three modes, we strongly encourage the use of all three.

Learning Objectives

As broad and flexible as the goals of LE in engineering may seem, it is still possible to define and assess many specific LE learning objectives. The following sections describe basic learning objectives that are broadly applicable to any engineering/technology program and that can reasonably be assessed in accordance with the ABET guidelines for program evaluation. The discussion is organized according to four broad categories: (A) communication, (B) professional responsibility, (C) technology and culture, and (D) intellectual and cultural perspectives.

A. *Communication*. Communication is the ability to convey information and ideas clearly and effectively to other individuals, both fellow engineers and society at large (i.e., non-engineers). In today's world, this includes an ability to communicate using written, oral, electronic, and visual/graphic media. Engineers work in a complex professional world. Over the course of a day, week, or career, they can find themselves communicating with other engineering professionals, with business and legal professionals, with managers, with support staff, with customers, with government officials, and with the general public. One day they might be selling a product to a customer, the next presenting an idea to a group of engineering colleagues, and the day after that introducing a project to the general public.

Therefore, an engineering education should provide students with a sophisticated understanding of the nature of communication and with opportunities to study and to develop skills for communicating the content and purpose of engineering over a wide range of audiences and in different settings. These skills include, but are not limited to,

1. Critical thinking skills
    - an ability to understand and analyze arguments
    - an ability to construct logical arguments based on evidence
    - an ability to present data and draw conclusions accurately and fairly, based on the use of critical reasoning skills

2. Communication strategies
    - an ability to articulate goals of a particular communication task
    - an ability to identify the audience of a communication task
    - an ability to design a piece of communication that achieves stated goals for specific audiences
    - an ability to recognize how human factors influence communication
    - knowledge of the problems inherent in conveying and interpreting information about technology-related risks
    - an understanding of the two-way nature of communication

3. Fundamental writing and presentation skills
    - knowledge of the basic rules of grammar
    - an ability to organize paragraphs and papers logically
    - a sensitivity to proper word use and an appropriate working vocabulary
    - familiarity with basic types of documentation and reference styles
    - familiarity with basic word-processing, presentation, graphing, and drawing software

4. Fundamental speaking and presentation skills
    - an ability to use oral communication to convey ideas and information
    - familiarity with the attributes of effective speakers and talks

B. *Professional Responsibility*. Engineering is more than "a job." When a student becomes an engineer, she or he assumes special responsibilities that require more than simply putting in hours or getting a job done. Engineers are society's technology professionals. We turn to them when we need advice on the design and operation of technology.

In turning to engineers for advice about technology, society expects engineers to act in accordance with the standards of good or accepted engineering practice. Therefore, an engineering education should provide students with opportunities to learn about the standards for good or accepted practice in their fields of engineering. Understanding the responsibilities engineers have as professionals includes, but is not limited to,

1. Professional organization
    - an ability to define the concept of "professionalism" and "professional responsibility"
    - an ability to describe the emergence of engineering as a profession
    - knowledge of the major professional organizations that are relevant to engineers

2. Professional codes of conduct
    - general knowledge of one or more general engineering codes, such as the NSPE Code
    - an ability to apply special engineering codes that are relevant to a student's field of interest to real engineering problems

3. Professional regulation
    - an ability to describe the different settings in which engineers work and the regulations that govern these settings
    - an ability to explain the ways in which society regulates the use of technology
    - an ability to explain the ways safety standards are set

4. Ethical reasoning
    - an ability to identify stakeholders in an engineering solution
    - an ability to identify moral problems and dilemmas
    - an ability to analyze moral problems from different ethical perspectives

5. Personal values
    - an ability to identify the personal values that the student holds and uses to resolve moral problems and dilemmas
    - an ability to describe the relationship between personal values, social values, and professional values

C. *Technology and Culture*. It is widely agreed by professional engineers that they have primary responsibilities to public health, public safety, and the environment. Accordingly, the responsible practice of engineering requires some understanding of the ways in which technologies impact individuals, society, and the environment. Therefore, an engineering education should provide students with opportunities to learn about the social context of technology. Understanding the social context of technology includes, but is not limited to,

1. History of science and technology
    - basic knowledge about changes in scientific and technological thinking over time
    - knowledge of the major changes in human culture that have resulted from scientific and technological developments
    - an ability to explain how the institutions that support and control science and technology have changed over time

2. An introduction to STS (science, technology, and society) studies
    - an ability to describe different approaches to studying science and technology
    - an ability to describe different theories about technological change
    - an understanding of common beliefs and assumptions about technology
    - an ability to explain how differences in belief and perspective lead to conflicting views about technology

3. Contemporary issues
    - an ability to identify and explain the major issues facing society today with regard to scientific and technological development
    - an ability to describe the different ways in which the major technological issues facing society can be debated and resolved

4. Social ideals and values
    - knowledge of the key social ideals and dynamics that have supported technological development and shaped engineering codes of ethics
    - an ability to evaluate both individual ethical decisions and proposed new technological undertakings in terms of social and ethical values
    - an appreciation for the perspectives of users and of the role of unintended consequences as a part of assessing the potential impacts of engineering decisions

D. *Intellectual and Cultural Perspectives*. The technical components of an engineering education provide students with a particular set of methodological tools and accompanying specialized information, developed in the context of a scientific framework. In their work, engineers will often need to interact with individuals who use different methods for solving human problems, sometimes based on fundamentally different ways of thinking and acting.

Knowing more about how others think and act can help engineers be more effective in their day-to-day interactions with others. Such knowledge can also enable them to reflect on their own assumptions and values, thereby enriching their work as engineers. Therefore, an engineering education should provide students with opportunities to explore different ways of learning and thinking about fundamental human problems. Knowing more about how others think and act includes, but is not limited to,

1. Fundamental assumptions about the nature of *reality* and *being*
    - an ability to describe and discuss the strengths and weaknesses of a scientific worldview
    - knowledge of different ways of thinking about nature (the physical world) as developed in other disciplines or societies

2. Ways of knowing
    - an ability to describe and discuss how engineers derive and use knowledge, with particular emphasis on the strengths and weaknesses of scientific methods and engineering design processes
    - knowledge of different ways of deriving and using knowledge, such as artistic, philosophical, and religious approaches to knowing

3. Politics, society, and cultures
    - an ability to describe and discuss how engineers make decisions about design options, technical standards, safety standards, and public policy
    - an ability to describe and discuss the ways in which society makes decisions about contemporary problems, such as global warming, energy consumption, environmental protection, sustainable development, and technological priorities

V. Assessment

Liberal education has been described in this report as a complex component of engineering education that touches students in a number of ways. At one level, it provides students with crucial *knowledge* and *skills* that are essential to the responsible and effective practice of engineering. At another level, it helps students develop *understandings* that round out and complement engineering design and decision-making. Finally, it helps students deepen their understandings of themselves and others, thereby enriching their *values* and *character*. To evaluate whether an engineering program has an effective LE component, attention needs to be given to learning outcomes at each of these levels.

In LE, as in other areas, assessment of outcomes provides useful information that indicates both how well a given program is succeeding and how it might be improved. While it is beyond the scope of this document to recommend specific approaches to assessment, the general process of assessment includes:

a) setting goals,
b) developing measurable objectives,
c) mapping where in the curriculum each objective is addressed (sometimes called a learning inventory),
d) deciding on what kinds of measures should be used to determine whether an objective has been met,
e) deciding on what constitutes evidence that the objectives have been met,
f) planning how assessment will be undertaken,
g) conducting the assessment, and

h) completing the assessment process through a feedback loop linked to future curriculum planning.

Gathering useful information for assessment and planning purposes requires: 1) ongoing efforts to develop more refined and useful methods for assessing LE objectives, and 2) continued focus on and articulation of these important objectives.

We encourage engineering educators to work closely with assessment experts on their campuses in planning assessment activities. Many people with H&SS expertise also have considerable experience with assessment. For example, social scientists may be able to help design effective surveys, and composition faculty often have extensive knowledge of rubric design and portfolio assessment. Collaboration with colleagues in other disciplines can lead not only to better assessments, but also to fruitful joint research. We also encourage triangulation--the use of multiple measures--when assessing student outcomes.

One of the strengths of *Criteria 2000* is that it provides guidelines, not prescriptions. Each institution and program is therefore free to define its own goals for its students, including the LE component of their education. However these are defined, they will no doubt include desired skills, understandings, and values, which can be addressed as follows when considering assessment:

Knowledge and Skills. As specific abilities, skills and knowledge are the easiest to assess, but their measurement requires careful thought and planning. In assessing professional education, one wants to look beyond a specific assignment or even a particular classroom to the situations students will face as practicing engineers. Will they be able to identify the audience when they have to communicate in practice? Will they be able to identify situations that raise questions about ethics or social consequences? Skills have no value if they are not used. Knowledge and skills may be assessed through

- standardized and locally developed examinations,
- simulations,
- performance appraisals, and
- surveys.

Understandings. Understandings result from the higher order thinking skills, which have been categorized by assessment specialists as: analysis, synthesis, and evaluation. Although these understandings are more difficult to assess than skills, they are obviously important for professionals (and citizens!) to possess. Understanding may be assessed through

- the use of portfolios,
- focus groups,
- performance appraisals,
- interviews, and
- other assessment methods.

Values and Character. Values are, of course, difficult but not impossible to measure. Once a program defines its desired outcomes for LE in engineering, there are various standardized instruments that help to measure values, moral development, and professional attitudes. In addition, reflective portfolios, interviews, and simulations may be helpful measures.

VI. Recommendations

Criteria 2000 provides an opportunity for engineering/technology programs to integrate LE into their curricula. To ensure that this opportunity is seized and that engineering students receive the education they need to become broadly educated, responsible professionals, we make the following recommendations:

1) All engineering/technology programs should have a comprehensive plan for LE in their curricula that at a minimum provides appropriate attention to all four broad categories of objectives (communication, professional responsibility, technology and culture, and intellectual and cultural perspectives) mentioned above.
2) Liberal education is an integral part of engineering education, rather than an extraneous requirement that students must meet. Therefore, comprehensive plans for LE in engineering/technology programs should strive to integrate LE with technical education as well as to serve the historic goals of liberal learning.
3) All engineering/technology programs should assess how well the LE components of their curricula achieve their established objectives. This assessment should include all three levels mentioned above (knowledge and skills, understandings, and values and character).
4) All engineering/technology programs should take steps to revise and improve the LE component of their curricula if they are not meeting the learning objectives set out in this report for a liberal education in engineering.
5) All engineering/technology programs should be encouraged to share examples of different ways in which the objectives outlined above could be met and to cooperate with the Liberal Education Division of ASEE in making these examples widely available.
6) ABET should take steps to involve liberal educators more fully in the assessment of engineering/technology programs.

VII. Conclusions

The approach outlined above blurs the boundaries between LE (also sometimes referred to as "general education") and engineering education in a way that we believe is beneficial. This beneficial blurring of boundaries, however, should not be allowed to obscure the distinctive value of liberal education for all students.

Although the phrase "liberal education" sometimes connotes a withdrawal from the concerns of the world, the traditional goal of LE in engineering has been to enable graduates to function actively and effectively in society. The complexity of society means that a broad base of knowledge and skills is needed and relevant. Moreover, the difficulty of predicting the demands of the future makes it impossible to specify exactly what knowledge and skills will be needed.

Consequently, one of the long-standing goals of LE has been to cultivate flexibility, open-mindedness, curiosity, and an understanding of the larger contexts in which decisions are made and problems are identified and solved.

The specific content of LE is no easier to specify than it has ever been, but the aims it seeks to achieve are at least as important now as they have ever been, especially given the rate of change that we experience and the role that technology plays in fueling change. The broad impacts of technology and the increasingly global context of engineering practice argue for a broad interpretation and a central role for liberal education as a part of engineering education. The ASEE Liberal Education Division stands ready to help in any way possible.

Acknowledgments

The White Paper had its genesis at the 2000 meeting of ASEE in a lively discussion provoked by Nicholas Steneck's suggestion that standards should be developed for LE as a component of engineering education. Assisted by Barbara Olds, Steneck headed up a working group whose members are listed below and who helped develop and critique the first version of a White Paper outlining the views of LED members on the definition of and goals for liberal education in engineering.

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