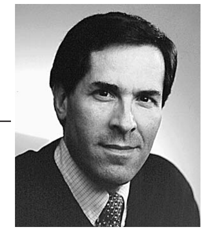
senior design capstone courses and ABET outcomes



Jay R. Goldberg

As a condition for accreditation, the Accreditation Board for Engineering and Technology (ABET) requires all undergraduate engineering programs in the United States to demonstrate that their programs produce 11 specific learning outcomes (ABET Criterion 3 Outcomes) [1]. These outcomes are specific abilities, knowledge areas, and attitudes that all students should possess upon completion of the undergraduate engineering program. ABET reviewers are looking for results of self-evaluations and assessments that prove that the required outcomes are being produced.

Biomedical and other engineering programs conduct reviews to determine which outcomes are met by the courses in their respective curricula. In situations where a specific outcome is not produced, programs are required to develop and implement plans for improvement to ensure that all requirements will be met. These plans may include development of new courses or modifications to existing courses. Programs must also document changes and eventually show that the changes resulted in improvements. The cycle of assessment, gap analysis, and change implementation closes the feedback loop and is very similar to the process required of companies by the ISO 9000 family of standards.

According to the *2006–2007 Criteria for Accrediting Engineering Programs* [1]: Engineering programs must demonstrate that their students attain:

a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for and an ability to engage in lifelong learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Biomedical engineering programs must also

> demonstrate that graduates have an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology; the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems. [1]

Many capstone senior design courses include lectures to develop students' knowledge of the product development process, project management, professional engineering practice, and the regulatory, legal, ethical, and economic aspects of medical device design. They also provide students with the opportunity to develop design, communication, and interpersonal skills through a team based project experience. Many of the ABET Criterion 3 Learning Outcomes focus on the development of the same knowledge areas and skill sets emphasized in senior capstone design courses. Thus, these courses can play an important role in helping undergraduate engineering programs meet many of the ABET learning outcome requirements.

A thorough assessment of a well-designed senior capstone design course can indicate to what degree the course can assist the program's efforts to meet the requirements. For example, a recent self-assessment of the capstone senior biomedical engineering design courses at Marquette University was conducted by the biomedical engineering faculty. The faculty developed a list of performance criteria that could be used to indicate that a specific learning outcome was being produced (performance indicators). They also developed a list of assessment tools such as exam questions, final reports, oral presentations, and other course deliverables that could be used to demonstrate that performance criteria were met. For example, Outcome C (ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability) was assessed using the following performance indicators:

- defines customer needs
- defines design constraints
- offers alternative solutions
- defines problems to be solved
- defines project scope
- compares alternative solutions
- defends selection of final design
- build prototype to meet needs
- validates performance of prototype.

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pairs of female engineering students out to schools throughout the country for one week in January to educate students about engineering. Each 1.5-h presentation includes examples of engineering projects, personal engineering student experiences, an interactive engineering activity, and a discussion of how high school girls can consider engineering as a career. Before and after the presentations, students are surveyed. In 2004, they visited 20 high schools and one middle school and reached more than 1,500 students and teachers. Before the presentations, 13% female and 25% male students described engineering in positive terms. After the presentations, 78% female and 71% male students described engineering in positive terms. Students commented that they were now willing to consider engineering as a career [3].

Biomedical engineers are a much more diverse work force than other types of engineers. According to ACT, which collects enrollment statistics during administration of its college entrance examination, females represented only 18% of the potential engineering majors for the freshman class of 2002, yet represented 52% of all students selecting biomedical engineering as their specific major [4]. Perhaps this has to do with the relevance of our field increasing the quality of life for so many people. While communicating the relevance of engineering to high school girls is not the panacea for engineering diversity, it is a worthwhile first step to towards this goal.

Gail D. Baura (gbbook@mindspring.com) is vice president of research and chief scientist at Cardio-Dynamics in San Diego, California.

References

[1] M. Kam, "Why Janie won't go to engineering school? (Hint: Janie is not Dumb)," *IEEE Interface*, no. 4, pp. 2–4, Nov. 2005.

[2] "Extraordinary women engineers project needs assessment: Final report," Apr. 2005 [Online]. Available: http://www.eweek.org/site/news/Eweek/2005_EWEP.shtml

[3] MIT Women's Initiative, Mar. 2006 [Online]. Available: http://hkn.mit.edu/wi/ home/index.php

[4] "Maintaining a strong engineering work force: ACT policy report," 2003 [Online]. Available: http://www.act.org/path/policy/pdf/engineer.pdf

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These performance indicators were evaluated using the following assessment tools (team-written documents that are required deliverables of the courses):

- ➤ Project Definition Document: contains project objective statement (which defines problem and project scope), existing solutions, and design constraints
- ➤ Customer Needs Document: contains list of customer needs along with design constraints
- ➤ Generated Concepts Document: contains potential solutions generated by project team
- ➤ Final Concept Document: defends selection of proposed final design
- ➤ Experimental Verification Document: contains test protocols, test results, data analysis, and conclusions regarding how well prototype meets performance requirements
- ➤ Final Report: contains final design, test results, information regarding how well customer needs were met
- ➤ Prototype

The results of the assessment indicated that upon completion of the two-course capstone senior design sequence most students were demonstrating the abilities, attitudes, and mastery of knowledge required by ABET learning outcomes a–k. There were components of the two courses that contributed (to different degrees) to the production of each of the learning outcomes. For example, because of the project team experience, the course played an important role in producing outcome d, that is, the ability to function on multidisciplinary teams. However, due to the structure of the course, it played a negligible role in producing outcome i, the recognition of the need for, and an ability to engage in lifelong learning. Each course in the curriculum contributed to the production of some of the learning outcomes. However, when assessed along with other courses in the curriculum, the program was shown to produce all of the ABET learning outcomes.

In summary, capstone senior biomedical engineering design courses typically include a wide variety of lecture topics and provide students with many opportunities to develop design, communication, and interpersonal skills. This learning environment can play an important role in producing the desired ABET learning outcomes. Careful identification and assessment of appropriate performance indicators using the appropriate assessment tools can help a biomedical engineering program determine the role of their capstone senior design course in producing the desired ABET learning outcomes.

Thank you for your time. You can contact me at jay.goldberg@mu.edu.

References

[1] *2006–2007 Criteria for Accrediting Engineering Programs*, ABET, Inc. [Online]. Available: http://www.abet.org