Integrating Soft Skills in a BME Curriculum

Paul Benkeser and Wendy Newstetter
Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology and Emory University

Abstract

ABET's Criterion 3 requires engineering programs to demonstrate that its graduates possess a number of "soft" skills related to the practice of engineering. These include skills related to teamwork, communications, professionalism, ethics, life-long learning, impact of engineering solutions, and knowledge of contemporary issues. Too often programs seek to satisfy this criterion through what might be called an "inoculation" approach, i.e. giving students a dose of ethics, communications, etc. in the form of a course. Teaching these skills in isolation of the professional practice of engineering has been shown to be a less-than-ideal approach. In contrast, the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University has chosen to develop an approach in which these skills are developed in the students through the use of problem-based learning (PBL) experiences infused throughout the curriculum. Separate problem-based learning courses are positioned in the first and second years. PBL experiences are incorporated into instructional laboratories associated with third-year systems physiology and biomedical sensors courses. The curriculum culminates with a two-semester senior design course sequence, which is a natural extension of the PBL experience. In addition to illustrating how we have incorporated PBL experiences in our curriculum, this paper will include examples of problems, tools, and assessment techniques designed to promote the learning of these soft skills.

Introduction

In order to achieve ABET accreditation, engineering programs must demonstrate achievement of a minimum set of program outcomes, as described in ABET's Criterion 3. These outcomes are statements that describe skills that "students are expected to know or be able to do by the time of graduation from the program."[1] A closer examination of these skills suggests that they can be divided into two sets as illustrated in Table 1. The first set, one which engineering educators are typically adept in both teaching and quantitatively measuring achievement, we will refer to as "hard" skills. The second set, which is more difficult to teach and assess, we will call "soft" skills. The integration and assessment of these soft skills in the biomedical engineering curriculum will be discussed herein.

Hard Skills	Soft Skills
an ability to apply knowledge of mathematics, science, and engineering	an ability to function on multi-disciplinary teams
an ability to design and conduct experiments, as well as to analyze and interpret data	an understanding of professional and ethical responsibility
an ability to design a system, component, or process to meet desired needs	An ability to communicate effectively
an ability to identify, formulate, and solve engineering problems	the broad education necessary to understand the impact of engineering solutions in a global and societal context
a knowledge of contemporary issues	a recognition of the need for, and an ability to engage in life-long learning
an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	

Table 1. Program outcomes specified in ABET Criterion 3

Operationalizing Criterion 3 Soft Skills

Before setting off to determine how best to develop soft skills in students, it is necessary to establish operational descriptions for these constructs. Such descriptions serve two functions. They reveal the complexity of the particular skills in terms of the sub-skills required to demonstrate the higher level skills specified in the ABET lists. Descriptions can also serve as articulations of learning outcomes, which can be designed towards and assessed. The following represents our interpretation of the variables that are indicators of these constructs.

Ability to <u>communicate</u> effectively

Oral + written communication skills

- convey information and ideas accurately and efficiently
- articulate relationships among ideas
- inform and persuade
- assemble and organize evidence in support of an argument
- give enough but not too much detail
- make communicative purpose clear
- provide sufficient background to anchor ideas/information
- be aware of and address multiple interlocutors
- clarify conclusions to be drawn from information
- avoid jargon

Ability to function on multi-disciplinary teams

Team/collaboration skills + communication skills (See above)

- help group develop team goals
- willingly forego personal goals for team goals
- avoid contributing excessive or irrelevant information
- confront others directly when necessary
- give emotional support to others
- demonstrate enthusiasm and involve
- complete tasks on time.
- monitor group progress
- stick to main themes without meaningless side tasks
- facilitate interaction with other members

Understanding professional & ethical responsibilities[2]

- recognize moral problems and issues in engineering
- comprehend, clarify, and critically assess opposing arguments
- form consistent and comprehensive viewpoints based on facts
- develop imaginative responses to problematic conflicts
- think clearly in the midst of uncertainty and ambiguity
- appreciate the role of rationale dialogue in resolving moral conflicts
- ability to maintain moral integrity in face of pressures to separate professional and personal convictions

Broad education necessary to understand the impact of engineering solutions in a global and societal context

- identify human needs or goals technology will serve
- analyze and evaluate the impact of new technologies on economy, environment, physical and mental health of manufacturers, uses of power, equality, democracy, access to information and participation, civil liberties, privacy, crime and justice.
- identify unintended consequences of technology development
- create safeguards to minimize problems
- apply lessons from earlier technologies and experiences of other countries

Recognition of the need for, and an ability to engage in life-long learning

- identify learning needs
- set specific learning objectives
- make a plan to address these objectives
- evaluate inquiry
- assess the reliability of sources
- evaluate how the sources contribute to knowledge
- question the adequacy and appropriateness of forms of evidence used to report back on learning needs
- apply knowledge discovered to the problem

Conventional Method of Teaching Soft Skills

*A*ll too often engineering curricula employ the "inoculation" model for teaching soft skills to the students. In this model, it is assumed that students can learn these soft skills by simply taking isolated courses in ethics, technical communications, etc. There are several problems with this model. It can decontextualize these skills, treating them as add-ons and not an integral part of every-day engineering practice. This is a false and even dangerous message to give the students - that written and oral communication and ethical behavior are peripheral to the real world of engineering. This message is further driven home because the faculty responsible for teaching these skills is humanities or social science faculty not engineering faculty. In addition, the complexity of these skills to be learned is too great for students to master within the framework of isolated courses. Nevertheless it is not uncommon for engineering schools to cram all of these skills into the final capstone design course. Somehow this is to be the magic bullet in which all these skills suddenly coalesce through one design experience. Research suggests, however, that students need quasi-repetitive activity cycles and practice in multiple settings to develop proficiency.[3]

Integrative Approach to Soft Skills Development

The Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University has begun to implement an integrative approach to the development of these soft skills in its undergraduate biomedical engineering degree program. This approach anchors soft skills development in the context of problem solving and design experiences over the 4-year curriculum. It provides multiple opportunities for the students to work on and develop skills and knowledge in a variety of "real-world" engineering settings in which these soft skills are practiced.

This approach requires that courses throughout the curriculum be identified as venues for soft-skills development to occur. In the Coulter Department we have selected six courses as venues, as described in Table 2. In each course, the need for real-world problems cannot be overstated. Authentic, open-ended problems are needed as contexts and catalysts for the development of these soft skills. Not only do they help prepare students for the professional practice of engineering but they are also a significant motivator for the students to delve more deeply into the problem-space. Moreover, the use of these skills in the context of a large problem makes them central not peripheral to biomedical engineering problem solving. They begin to understand the value of clear, thoughtful communication and collaboration when confronting complex problems. They see how ethical issues can arise when seeking design solutions. If the problems are authentic, then the information needed to solve them must be found in multiple places, which helps students to develop inquiry and research skills for life-long learning. Experience tells us that when students tackle ill-structured, ill-constrained problems with others they must engage with and utilize the soft skills to achieve success. As example of a problem we use in our first BMED class is included in Figure 1.

In Search of a Treatment for Huntington's Disease
Huntington's Disease (HD) is a degenerative brain disorder for which there is, at present, no effective prevention, treatment or cure. HD slowly diminishes the affected individual's ability to walk, think, talk and reason. Eventually, the person with HD becomes totally dependent upon others for his or her care. Huntington's Disease profoundly affects the lives of entire families: emotionally, socially and economically. Your group is preparing a preliminary research proposal to Huntington's Disease Society of America (HDSA). HDSA is planning to expand its research programs to fund research groups for up to 10 years at a level of $2M per year in direct costs. Your job is to recommend to HDSA a treatment (not cure or prevention) strategy that has the potential to offer the greatest quality of life improvement for those afflicted with HD. The chosen strategy would have to be one that could be developed within the 10-year time frame. Your recommendation should take into consideration both the research conducted in this field to date and public policy concerns that may affect the acceptance of such a strategy. Your preliminary proposal must include the following: 1) a justification for the chosen strategy based upon a demonstrated understanding of the pathophysiology of HD, 2) a detailed explanation of how the chosen strategy would work, and 3) the technical, regulatory and public policy barriers which could affect the ability of a company to market such a strategy.

Figure 1. Example PBL problem

Within each experience detailed in Table 2, activities are identified within the problem-solving cycle that helps students build these soft skills. These activities, and tools to support those activities are described in Tables 3 and 4, respectively.

Course	Experience(s)	Location within Curriculum
BMED 1300 Problems in BME I	3 to 4 PBL problems	1st year
BMED 2300 Problems in BME II	4 PBL problems	2nd year
BMED 3161 Systems Physiology II	design project	3rd year
BMED 3500 Biomedical Sensors and Instrumentation	design project	3rd year
BMED 4600/4601 Senior Design Project I/II	design project	4th year

Table 2. Courses with integrative soft skills development

Activity	Soft Skill				
	Communicate	Teams	Responsibilities	Impact	Learning
Identifying learning/knowledge needs as a team/individual					X
Acquiring knowledge needed to solve problem			X	X	X
Reporting back to team	X	X			X
Digging deeper and solving	X	X	X	X	X
Presenting solution to audience of experts	X				
Writing a report on problem solution	X				

Table 3. Repetitive activities in the problem cycle

Activity	Tool				
	Facilitators	Peer/Instructor Evaluations	Instructor Lectures	Report/Presentation Templates	Co-Web[4]
Identifying learning/knowledge needs as a team/individual	X	X			
Acquiring knowledge needed to solve problem	X	X	X		X
Reporting back to team	X	X	X		X
Digging deeper and solving	X	X			
Presenting solution to audience of experts		X	X	X	
Writing a report on problem solution		X	X	X	X

Table 4. Tools to support activities

For developing team skills, the students are required to work in teams for all these experiences with the possible exception of the senior design project. These teams range in size from as small as two students for some design projects, up to eight students for the PBL experiences. To support the development of communication skills, students are required to communicate their problem solutions/designs in both oral or poster presentations and written reports. The students receive feedback from both their peers and instructors/facilitators on the strengths and weaknesses of their communication skills. The students develop life-long learning skills through the assignment of experiences that require them to perform self-directed inquiry to uncover information from a variety of sources necessary to progress towards a problem/design solution. Self and peer evaluations as well as instructor/facilitator evaluations are employed in each course to help the students monitor the development of their inquiry, team, and communication skills.

Careful selection of problems is necessary to ensure that the experiences allow the students to explore professional and ethical responsibilities and the impact of engineering solutions in a global and societal context. Fortunately, the problem space for the field of biomedical engineering is filled with topics that capture considerable mass media, and therefore student, attention. For example, Figure 1 contains a problem that we have used in the first PBL course. The solution space for the problem could include cellular/genetic engineering, fetal tissue implants, and stem cells. While addressing ethical concerns is not spelled out in the problem statement, students will inevitably find themselves in positions where all members of their group do not share their perspectives on these concerns.

Discussion

The development of this integrative approach began in the fall semester of 2001. The approach will be fully implemented in the spring semester of 2004. At that time the Coulter Department will have its first graduates from the program. Because we are taking an integrative, four-year problem-based approach to the development of these skills, we have numerous assessment challenges. First, we have to divide our assessment questions into two categories: those that address measuring the achievement of Criterion 3 skills, and those that address the value added to the development of these skills by this integrative approach we have embarked on.

Achievement of soft skills related to Criterion 3 outcomes are being assessed at multiple points in the curriculum. For example, oral and written communication skills have been assessed in presentations and reports in BMED 1300 and 2300 for almost three years, and will be assessed in 4601 for the first time in the spring semester of 2004. When the 4601 data is collected, we will be able to assess the success of the integrative approach. After the initial assessment of the level of achievement of these outcomes, the current plan is assess each outcome every other year so as not to overwhelm those responsible for implementing the plan.

When addressing value added assessment questions, it is important to recognize that students will be entering our program with different levels of competency in these skills. For example, students who have participated in high school debate teams may well possess better communication skills than the typical student. To understand the effects of this approach we need to develop baseline assessment tools to profile students as they matriculate that we can use at the time of graduation for comparison purposes. Data collection would have to be extended beyond the time of graduation in order to assess the short-term versus long-term effects of the integrative approach. In addition, it is important to balance individual assessment of skills development within the collaborative learning environment that calls for group-generated products. To help achieve this we require students to write bi-weekly memorandums addressing their individual activities within their group.

In summary, in order to foster the development of the soft skills within Criterion 3 we believe each skill must first be unpacked to reveal its complexity before it can be determined how best to teach those skills to the students. This has presented us with both numerous assessment challenges and opportunities for program improvement.

Bibliography

1. Criteria for Accrediting Engineering Programs, ABET Engineering Accreditation Commission, 2004. Available at http://www.abet.org/criteria.html (14 January 2004).
2. M. Martin and R. Schinzinger, *Ethics in Engineering*, McGraw Hill, 1997.
3. S. Brophy, "Constructing Sharable Learning Materials in Biomedical Engineering Education," IEEE Eng. Med. Biol. Mag., 22:4, pp. 39-46, 2003
4. M. Guzdial, J. Rick and B. Kerimbaev, "Recognizing and Supporting Roles in CSCW," Proceedings ACM CSCW 2000, Philadelphia, PA., 2000. Available at http://coweb.cc.gatech.edu:8888/csl/uploads/cscw2000.1.pdf (14 January 2004).

Biographies

PAUL J. BENKESER is an Associate Professor and Associate Chair for Undergraduate Studies in the Department of Biomedical Engineering at Georgia Tech and Emory University

WENDY C. NEWSTETTER is Director of Learning Sciences Research in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.