Can ABET Professional Skills Stimulate Curriculum Changes That Aid in Student Recruitment?

Larry N. Bland
John Brown University

Introduction

In November 1996, the Accreditation Board for Engineering and Technology (ABET) board of directors approved one of the most significant changes to accreditation of engineering programs in modern times. Previous accreditation requirements had been a very rigid set of rules from almost thirty pages of detailed requirements that covered course requirements, credits and distribution, faculty staffing, and laboratory facilities. [1] The new criteria became known as Engineering Criteria 2000. These new requirements were reduced to three pages. The stringent rules had disappeared. More general criteria were established. Each university was now responsible for defining and assessing their program within these criteria.

Criterion 3 is a key, new criteria element– a set of eleven outcomes that all undergraduate engineering programs must meet. These outcomes separated into two categories; "hard" skills and "professional" skills. The current hard skills include: [2]

- An ability to apply knowledge of mathematics, science, and engineering;
- An ability to design and conduct experiments, as well as to analyze and interpret data;
- 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;
- An ability to identify, formulate, and solve engineering problems;
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The current professional skills include:

- An ability to function on multi-disciplinary teams;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues.

It is this second set of outcomes that creates the foundation for this paper. These skills have been controversial within the engineering community. Some individuals look at this as interference to our main purpose of teaching the hard skills. Others see them as a very necessary part of preparing our students for future career needs.

In this paper, I will look at some of the literature that establishes the context for these skills, what other institutions have done in the areas of service learning and global studies to meet these needs without jeopardizing the hard skills, offer an alternative for consideration, highlight some areas of concern and identify areas of engineering educational research that need to be addressed. As the above areas are covered, reports from various institutions cite how this may actually assist in diversity recruiting.

Context

The literature recognizes a need for engineering students to have a better understanding of the global nature of our society and the complexity that can arise in addressing and integrating societal, cultural and technological issues. The National Academy of Engineering projects that engineers of the future will see more widespread impact to their designs because of the political and economic relations among nations. Due to the global nature of business, designs will be developed to simultaneously need domestic and international needs. Engineering practice will be driven by attention to intellectual property, project management, multilingual influences and cultural diversity, moral/religious repercussions, global/international impacts, national security, and cost-benefit constraints. [3]

In 2000, Smerdon identified that "Perhaps there is no single factor of greater importance in its effect on engineering education than the internationalization of engineering practice." [4] His presentation very carefully brought together the findings from multiple studies and outlined many professional skills that would be necessary for future engineers to meet the challenges of a global workplace. A recurring theme that he recognized is that the engineer of the future will be continually changing as adjustments are made to the rapid changes of our world. That world involves rapidly changing technologies throughout the world, designing within an international context, and being cognizant of global societal, economic and ethical issues.

In 1994, the American Society for Engineering Education (ASEE) analyzed the changes needed for engineering education. [5] The report stated that engineering education program must be relevant, attractive and connected. Action items were identified to provide a better education in the professional skills for our engineering students. These action items culminated in the ABET initiative that became known as Engineering Criteria 2000.

A look at multiple reports of the National Research Council (NRC) indicates consistent recommendations to integrate science technology, engineering and mathematics (STEM) and liberal arts. [6] Not only do other students need to learn technical skills and processes, STEM students need educational interventions to improve their writing, communication skills and understanding of the needs of society as a whole. Current course content must consider and incorporate: cultural awareness, international business and communications issues, politics, social/cultural issues, global nature of technology, appropriate technology, [7] and minority/diversity considerations from a global perspective.

The National Research Council identified that one of the new concepts for improved learning incorporates cultural experiences and community participation. [8] However, engineering curricula changes at most institutions have lagged behind many other disciplines in incorporating globalization or service learning. [9] Engineering faculty have been primarily involved in advancing the hard, technical skills and advancing research in engineering sciences. Community and cultural activities have been performed in a voluntary, non-credit environment. Opportunities exist for these voluntary activities to be formalized into credit bearing learning experiences that would be learning centered and increase knowledge retention. [10]

The 2002 Project Kaleidoscope Report on Reports identified a consistent theme over seventeen years of reports: a vision of an environment where undergraduates develop an understanding of the role of science and technology in their world. [11] During that same time period universities have seen the needs of their student change due to changing demographics and diversity. Across the university curriculum we have added courses such as: International Business, Appropriate Technology, and Intercultural Studies. At my own university, student demographics have changed with the current undergraduate population being 40-50% Spanish speaking as either a first or second language. However, our course structure has remained relatively traditional being taught only in English and focused on scientific facts and technical designs for American companies and organizations.

Schools are currently re-evaluating their curricula, seeing the need for new learning centered education, and incorporating changes that will facilitate service learning and globalization initiatives. Consistent with the National Research Council (NRC) recommendations, they endeavor to integrate STEM and liberal arts. Concepts are merged such that the liberal arts student would participate in community courses to meet technical needs and at the same time reduce their fear and opposition to science and technology. Learning elements are incorporated for the STEM student to improve their writing, communication skills and understanding of the needs of society as a whole. [12]

In response to these inputs, many institutions are making curriculum changes in the areas of service learning and global studies. These changes create models to learn from and build on as engineering education is improved.

Service Learning

Contemporary learning theory stresses the tremendous learning opportunities that come from integrating service learning directly into academic programs. Jacoby and Associates define service learning as “a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development. Reflections and reciprocity are key concepts of service-learning.” [13]

Service learning has been strongly espoused as a pedagogical technique for meeting the ABET professional skills. These community-focused projects are developed to address multi-disciplinary, contemporary needs within social, political and economic environments. These projects often have ethical issues and require much communication between the engineer and the customer organization. By integrating the hard skills and the professional skills, the engineering educators and student fit more material into an already packed curriculum.

To date, there appears to be a shortage of engineering programs with service learning integrated into the curriculum. There are examples of service learning as applied to capstone design courses or directed studies courses.[14] Out of 11,800 service learning courses reported by 575 member campuses of Campus Compact, very few were a part of an engineering program. One of the most notable programs is the EPICS program started with NSF funds at Purdue University.

The Engineering Projects in Community Service (EPICS) has stated that undergraduate engineering students face a future where they will need more than just a solid background in scientific and engineering facts in order to succeed. As students set goals for any systems that they are asked to design, they will be expected to have a holistic understanding of the problem and potential solutions. The students will have to interact effectively with people with a wide variety of social, ethnic, cultural and educational backgrounds.[15]

The EPICS program uniquely integrates all of the following attributes: [16] community partners, large, vertically-integrated teams, long-term student participation, variable credit hours, multi-disciplinary teams, and start-to-finish design experience. The program embeds service learning into design projects. Teams are established and projects are negotiated with a non-profit community partner. Each team is vertically-integrated with freshmen, sophomore, junior and senior members and will function for several years. As a project is completed, new projects will be defined with the partner. As students graduate, team member will matriculate and new members are added each year to fill needs. Students may sign up for 1 or 2 credit hours per semester. Projects go through the phases of: establishing a partnership, assembling a team, project proposal, system design and development, and system deployment and support. This program has now been extended to a total of fifteen universities. [17]

There is anecdotal evidence that the service learning elements of EPICS improve attraction and retention into engineering programs, especially women and minorities. Purdue initiated its program in the Fall 1995 with forty students and five teams. Since its inception the program has continued to grow in both breadth and size. Currently there are over 400 students participating on 24 project teams. Over a five-year period, women have a significantly higher representation in EPICS than they do in the traditional engineering programs. Women constitute about 30% of EPICS team leaders. [18]

The EPICS program has functioned in parallel with traditional engineering programs and is not integrated into all programs. Students have the option of choosing either approach as they pursue their engineering education. The University of Massachusetts Lowell (UML) recently received an NSF Department Level Reform grant to integrate service learning across the entire engineering curriculum. Their stated goal is "Integrate service-learning into the engineering curriculum at UML so that every student is exposed to service-learning in every semester of their experience in every department at UML." This is a novel approach as they strive to spread service-learning as a requirement throughout their mainstream courses.[19] Pilot activities within their mechanical and electrical and computer programs have already been completed.

Within their proposal, UML cited various studies to support their initiative. Astin et al., [20] found service to be beneficial in student retention, increased community service post-graduation, improved racial interaction, improved civic responsibility and in development of a meaningful philosophy of life. A separate study by Eyler and Giles [21] found positive impacts of: tolerance of diversity, personal development, interpersonal development, and community-to-college connections. Students reportedly worked harder were more curious, connected learning and personal experience, and demonstrated a deeper understanding of the subject matter. UML is expecting positive cognitive and attitude development from their students as a result of this initiative.

Again, attraction and retention data are anecdotal in nature at this time. UML has predominantly been tracking data in their capstone courses. To date, they are experiencing an overrepresentation of women and older, more diverse students in these programs. They state "service learning appears to have the potential to attract and retain underrepresented populations in engineering through meaningful and experiential applications."[22] Although both UML and Purdue stated evidence of growth and retention due to their service learning programs, I did not find where either university has actively incorporate this factor as a part of their enrollment recruiting activities.

To meet the ABET EC2000 criteria, universities have also turned to global initiative and study abroad as a potential solution with a strong impact of student's futures.

Global Studies

The University of Rhode Island created an International Engineering Program (IEP) to address future student career needs.[23, 24] This program originally targeted studies in Germany speaking countries and later added French and Spanish. This is a minimum five-year program with the student enrolled in both engineering and language studies. Successful graduation results in the award of both a B.S. in engineering and a B.A. in a language. Again, this program targets many of the ABET professional skills such as functioning on multi-disciplinary teams, multi-cultural ethical responsibility, communications, global and societal context, life-long learning, and contemporary issues

The program includes a semester of study at a partner university and a six-month internship with a foreign corporate partner. IEP interns are usually provided housing by the company sponsor, and are paid a small stipend during their time abroad. Upon returning to the campus, the student writes a report of their semester studies in the foreign language of study. In addition to the study abroad, the on-campus language classes have been tailored to engineering requirements. Courses stress oral skills and everyday language rather than classical literature. Vocabulary has been integrated with terms from the fields of physics, computer science, chemistry and mathematics. There is a special interdisciplinary engineering course that is taught in a language by bilingual engineering faculty.

With the additional course load of the foreign language, the program planners wondered how well the IEP program would be received. Their projection was fifteen students for the initial cohort. Much to their surprise, forty-seven students signed up from the first freshman class. By the second year, program demands and other circumstances had reduced this number to twenty-five students with much more moderate attrition on subsequent years. The pattern appears to be about 20% of incoming freshmen will enter the course with one third of that group continuing to completion. Enrollment in the program is now about 175 students. An interesting piece of anecdotal evidence for diversity enrollment is that the female population for the college of engineering is 18%, but the IEP program has a female population of 31%. This program appears to attract the female engineer.[25]

The University of Rhode Island has been very active in disseminating the ideas, issues, and successes of their program. Under a grant from the U.S. Department of Education, they created an Annual International Colloquium on International Engineering Education. The eighth conference will take place in Atlanta in the Fall 2005. Through this effort many additional universities are now implementing similar programs.

Many engineering programs use service learning to meet humanitarian and community needs in international locations.[26, 27, 28] While some existing programs have integrated service learning with design courses, [29] multidisciplinary efforts, [30, 31] and co-curricular activities, [32] most such efforts tend to be little more than a senior capstone design course with an international client or destination. Actual student travel to these locations and focus on understanding the cultures has been limited. Technical solutions have been the focus and any understanding of cultures has been incidental.

For example, in both Guatemala and Uganda, JBU projects have brought new cook stoves into underdeveloped communities. These stoves solve multiple problems. The current cooking technology consists of open fire pits, usually directly on the floor of the living quarters. These have many inherent safety and health issues, not to mention high loss of energy from the combustion process, resulting in rapid deforestation of the local communities.

The new stoves provided through the JBU projects are enclosed and vented. This eliminates human exposure to direct flames while also eliminating noxious fumes from the home, resulting in fewer accidents and improved health. The new stoves operate with higher efficiency and significantly reduce the amount of fuel consumed, which directly affects the quality of the local environment. The projects in both countries have resulted in income-producing enterprises that are locally sustainable.

The examples discussed above have been facilitated on an informal basis by a limited number of people. No course hour credit was provided. The time in country was limited to one or two weeks that did not provide for immersion into the culture. The results to the host community were significant, but the cultural development of the students was limited.

Alternative

Not all students can travel internationally. Thus, some schools envision an on-campus Global Studies course to bridge the gap for those students who cannot participate in the study abroad program. Schools like Georgia Institute of Technology require this type of course prior to going overseas. While a Global Studies course includes no lab or technical design component, the class will incorporate active learning with discussion, debate, team/panel discussions, role-playing, and cross-cultural interviews. To accomplish the understanding and reflection of other cultures in a global workplace, assignments are designed for interviews and reflection on the impacts of society and culture on the students' designs, their lives and careers. Cross-cultural interviews and other experiences may be facilitated by close proximity to the headquarters of several Native American nations, a growing local Hispanic population, the fact that a campus has a significant international student population or other local ethnic groups.

The course also incorporates learning elements for STEM students to improve their writing, communication skills, and understanding of the needs of society as a whole.[33] The course content incorporates many of the professional skills plus understanding societal problems, design and manufacturing that emphasize locally available resources and skills, attention to sustainability, potential life-style impacts, [34] and minority/diversity considerations from a global perspective. The courses will challenge engineering students to understand other cultures and how their profession can have a direct societal impact on people around the world.

Some of the objectives that universities have stated for these courses are:

- Provide students with a significant knowledge base concerning historical, social, economic, and political systems of one or more contemporary cultures.
- Focus on the worldview, religion, and values of one or more contemporary cultures.
- Address issues of cultural conflict within or between nations.
- Foster among students an understanding of social and cultural change.
- Provide familiarity with an area of the world or a country that allows them to make systematic comparisons with their own society and culture.

Concerns

As these learning centered programs are planned for implementation, academic integrity, faculty workload, and logistical issues have arisen as areas of concern.

Academic integrity: Serious consideration must be given to maintaining the academic integrity of the endeavor while incorporating global and service components. Ten best practices have been identified as keys to maintaining academic integrity when incorporating site-based or service learning:[35]

- Academic credit is for learning, not for service or travel.
- Do not compromise academic rigor.
- Set learning goals for students.
- Establish criteria for the selection of community service placements.
- Provide educationally sound mechanisms to harvest the community learning.
- Provide supports for students to learn how to harvest the community learning.
- Minimize the distinction between students' community learning role and the classroom learning role.
- Rethink the faculty instructional role.
- Be prepared for uncertainty and variation in student learning outcomes.
- Maximize the community responsibility orientation of the course.

Tested pedagogical processes must be maintained during course development. Courses development proceeds from understanding the audience, to establishing course goals and objectives, determining appropriate teaching methods for each situation, choosing texts if appropriate, coordinating with other faculty and partners, preparing syllabi, determining evaluation and assessment criteria, and making all arrangements for the learning experience to begin and proceed to a successful conclusion.[36, 37, 38] These elements of course development do not change with service learning or global study abroad. But the added complexity of community negotiations or foreign settings enhances our classical approach.

Faculty workload: Campus Compact is a coalition of more than 950 colleges and universities committed to incorporating civic purposes into higher education. In their 2002 survey (response rate of 60%), they stated that "time and faculty teaching loads (64%) and a lack of common understanding of the concepts and models of service-learning (44%) were the most commonly cited obstacles to the extension of service-learning on campuses." [39] These challenges have been consistently identified in previous surveys and continue to be barriers to overcome.

Universities basically have addressed these issues, for both service learning and study abroad, in two ways. First, they have recognized the added complexities that exist in these programs. Additional funding from university resources, external support or both has been pursued to provide release time for managing the overall programs. [40] This provides the faculty members time to manage the program from student recruiting, to program implementation and final career placement. Community organizations and private enterprise have developed strong cooperative arrangements with universities to provide some of the support.

The second issue of faculty understanding has been addressed with campus workshops and colloquiums. The faculty members not only look at how to develop these courses, but they also must be convinced of the learning effectiveness of these teaching methods. Campus Compact provides various toolkits to equip universities and their faculty from introductory, to intermediate and advanced levels of involvement. Many of the study abroad issues are also being addressed at the annual colloquium of the ASEE/AaeE Global Conference, the annual ASEE Conference, and the Colloquium on International Engineering Education.

Logistics: For study abroad programs, international logistics can present some interesting challenges. Course planning goes beyond just focusing on the content to include careful consideration of potential logistical issues. Good planning assures that the holistic experience functions properly. Experiences abroad indicate that a properly planned educational experience must make provisions for food, housing, transportation, communications, health care, student safety, and social activities. To ignore any portion of the total experience may be detrimental to the educational opportunities that exist.

For example, many engineering projects may ship supplies and goods into a country for students to complete their assignments. Custom duties and processes can create barriers to a successful international task completion. There are documented instances where service learning/international projects have had reduced success due to logistical issues. [41, 42] Issues may also exist for immigration and visas. Faculty must pursue projects aware of the need for proper focus to logistical details, customs and immigration. A successful implementation phase will be predicated on giving appropriate detail to these issues under planning phases.

Educational Research

For the engineering education community, the opportunity for research is wide open. The reader may have noted that every time I addressed attraction and retention I also stated that the information is anecdotal in nature. There is anecdotal evidence, but no known formal research data, that concludes that incorporating global studies or service learning elements into engineering courses improves attraction and retention, especially among women and minorities.[43, 44] Research models need to be developed for both service learning and global studies, data must be collected and results disseminated to engineering educators. The University of Massachusetts Lowell [45] and Massachusetts Institute of Technology [46] currently have NSF grants to develop models and assessment tools for portions of service learning. They are taking some of the first steps in filling this need.

As stated earlier, faculty must be convinced of the effectiveness of these teaching pedagogies. The very ABET criteria that mandated the professional skills also left the interpretation of outcomes and assessments up to each individual school. Shuman, Besterfield-Sacre and McGourty [47] noted that much work remains to be done in assessment of these professional skills. The literature is sparse when it comes to robust, effective outcome measurements. They proposed that three hurdles impeded the development of viable tools to assess engineering student attainment of these outcomes: consensus about definitions, scope by which the outcome is assessed, and nature of the outcome itself. Research projects need to be developed to fill this void. Research needs to be both formative and summative in nature. Current course activities indicate that both pre- and post-assessment is needed to identify the learning changes that take place.

For study abroad research there is no need to restrict the research subjects to only our engineering students that travel abroad. Four distinct groups of global studies participants are available at most universities. The first group would be those students taking an on-campus global studies course. This group would be considered a control group that has not been immersed in a foreign culture. The second group would be those engineering students enrolled in university study abroad programs. The third group would be international students that are enrolled in on-campus classes. They also are in a study abroad activity, but their foreign country is the United States. The fourth group would include students from the liberal arts or other professional programs that are participating in other study abroad programs. There is much information that can be shared between engineering education and the liberal arts. [48] The inclusion of these various data collection groups will: 1) increase the sample size of the study, and 2) test the validity of the research instruments with diverse groups. Definitions, theory and convergent results will emerge from the data collection.

Conclusions

Can ABET Professional Skills Stimulate Curriculum Changes That Aid in Student Recruitment? This is our original question. The ultimate answer to this question remains open. Many universities are incorporating the learning centered pedagogies of service learning and study abroad into their curriculum with positive results. Recent publications have been very supportive of using these pedagogies in teaching the professional skills without reducing academic content. [49] But a lot of opportunity remains to develop research results on attraction, retention and effectiveness. The engineering educational community must step forward and accept the challenge of filling this research void while we pursue innovative teaching methods.

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Biography

LARRY N. BLAND
Larry Bland is currently an Assistant Professor of Engineering at John Brown University. Dr. Bland has been at John Brown since 2002. Prior to his academic career, he spent over 30 years in industry. His industrial career moved from engineering to executive management with significant international experience. Since joining John Brown, Dr Bland has been active in improving the engineering recruiting efforts.