2006-1222: INCREASING INTERNATIONAL AWARENESS OF ENGINEERING STUDENTS

Angela Bielefeldt, University of Colorado-Boulder

Dr. Bielefeldt is an Associate Professor and a licensed P.E. in the State of Colorado. She teaches Civil Engineering courses for freshman, seniors, and graduate students on topics including hazardous waste management, solid waste management, and bioremediation. She is a co-faculty advisor for the Engineers Without Borders student chapter at CU-Boulder and is working with other faculty at CU to start a new emphasis in Engineering for Developing Communities at both the graduate and undergraduate levels.

Increasing the International Awareness of Engineering Students

Abstract

Changes have been made over the past two to three years in the 1-credit "Introduction to Civil Engineering" course at the University of Colorado to incorporate international aspects. This promotes aspects advocated by the National Academy of Engineering in "The Engineer of 2020" report: "…we must develop and implement more ecologically sustainable practices… in industrialized countries and developing countries alike [using]…systems-based strategies and holistic approaches that embed social and cultural objectives." The goals of the course include describing civil engineering, what civil engineers do, providing a framework for evaluating ethical behavior, and showing the breadth and excitement of the civil engineering profession. Case study examples of civil engineers and civil engineering projects now include humanitarian aid in refugee camps and the Three Gorges Dam in China. Students are required to attend a meeting of an engineering professional society, and the student chapter of Engineers Without Borders (EWB) has proven to be a popular option. The recent changes in this course fit with a long-term plan to create an "Engineering for Developing Communities" certificate program for undergraduate students in the College of Engineering.

Background

An awareness of international issues is increasingly important for engineers, who are now competing and working in a global economy. In addition, it is important for engineers to understand that their work can have global implications and may impact the longterm viability of life on the planet. Beyond humanitarian motivations, we ignore the developing world at our own peril. Their development may have worldwide impacts such as global warming and global circulation of pesticides.

According to the ABET criteria for accrediting engineering programs[1], graduating students must have:
(h) [an understanding of] *the impact of engineering solutions in a global, economic, environmental, and societal context*
(c) *an ability to design a system... to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
(j) a knowledge of contemporary issues
International case studies provide one tool for achieving these goals.

Furthermore, the National Academy of Engineering's "Engineer of 2020" report[2] notes:

- *we must develop and implement more ecologically sustainable practices… in industrialized countries and developing countries alike*
- *The engineer of 2020 will have to understand how to adapt solutions [suitable for industrialized countries], in an ethical way, to the constraints of developing countries*

Although there are many opportunities throughout an engineering Bachelor's degree to incorporate these concepts, making students aware of the importance of these aspects early on in their education may be particularly effective.

Introduction to Civil Engineering course overview

At the University of Colorado, each of the engineering majors offers a one-credit introductory course for freshman students. Many students enter engineering without a clear understanding of what engineering is, what engineers do, and if engineering is a good career choice for them. This introductory course tries to help answer these questions. The course also tends to attract students who are undeclared engineering majors or even students from the College of Arts and Sciences that have not yet selected a major.

Many of the most urgent needs for engineering solutions are present in the developing world. It is estimated that 40% of the world's population lack adequate sanitation, and 20% lack clean water and adequate housing[3]. These problems will only worsen over the coming years, as it is anticipated that over the next two decades that 95% of the expected global population growth of two billion people will occur in developing or under-developed countries. Civil engineers will have a critical role to play in improving the quality of life and sustainability of people around the world. Making potential future engineers aware of these needs may be motivational.

I have taught the *Introduction to Civil Engineering* course at the University of Colorado nine different semesters since 1997 (http://www.colorado.edu/engineering/civil/CVEN1317/syllabus.html). Over that time, the specific course content has changed many times. But the basic goals of the course have remained the same:

1. describe what civil engineering is and civil engineers do
2. establish a context for using the information students are learning in other courses
3. provide a framework for evaluating ethical behavior
4. show the breadth and excitement of the civil engineering profession

Over the past two to three years, international aspects have been added to the course. This has been complementary with an emerging *Engineering for Developing Communities* (EDC) program (http://www.edc-cu.org/). Long term plans are underway to offer a certificate to undergraduate students in EDC. Specific areas of the course that have been modified to add international aspects are highlighted below. An overview of the number of students enrolled in the course (grouped by year in school and their academic major) over the past 5 years is summarized in Table 1 below. Most of the enrolled students were freshman, and some sophomores. Most of the non civil engineers were either open option (undeclared majors) in the College of Engineering or in the College of Arts and Sciences. Note that student assignments were only culled for informative statements in 2003 and 2004.

Table 1. Student Enrollment in Introduction to Civil Engineering course

Students	Fall 2001	Fall 2002	Fall 2003	Fall 2004
Freshman Civil Engineers	14	21	28	25
Freshman from other engineering majors	2	6	10	11
Freshman from non-engineering majors	3	6	7	10
Sophomore – Senior Civil Engrg students	10	5	8	3
Sophomore – Senior other Engrg students	1	3	1	1
Sophomore – Senior non-Engrg students	1	6	9	2
Total Enrollment (at end of course)	31	47	63	52

Ethics Module

One goal of the course is for students to learn about professional ethics. The students download the code of ethics from both the National Society for Professional Engineers (NSPE) and American Society of Civil Engineers (ASCE). They then use these codes to discuss the ethical considerations involved in a number of case studies available from the Online Ethics website (http://onlineethics.org/). From Fall 1999 to Fall 2002, the assignment also had the students read about LeMessurier as an example of a moral exemplar (http://onlineethics.org/moral/index.html). LeMessurier is the structural civil engineer who designed the Citicorp tower in New York. In Fall 2003 and Fall 2004, students selected one of three moral exemplars to read about: LeMessurier, Inez Austin, or Fred Cuny. Inez Austin was a whistle-blower for environmental concerns at Hanford, WA. Cuny was a disaster relief specialist who did humanitarian engineering work in Chechnya, Ethiopia, Bosnia, Somalia, etc.

During the in-class discussion, a number of students had selected the Cuny case and stated that they hadn't previously considered the application of civil engineering to refugee camps from natural and conflict disasters. In their reflective essays on Civil Engineering that are due in their Journals at the end of the semester, some students commented on the Cuny case study. For example, one male student in 2003 noted: "I mostly enjoyed learning how Civil Engineering impacts communities. The case study [of] Fred Cuny's humanitarian work impacted me the most. [Cuny] used his engineering knowledge to help communities in less fortunate countries resolve their problems. Reading about this amazing person compelled me to want to help other people the way that he did." One of the women students noted: "This course... opened new possibilities for me. I was surprised and interested to read the case studies, especially the international and service aspects of Cuny's work." None of the other ethical exemplars were named in the final student essays, indicating that the Cuny case was particularly influential.

Although the feedback on the ethics assignment during the semester seemed neutral to somewhat positive, the end of semester student write-in comments on the Faculty Course Questionnaire (FCQ) did not really indicate this (see Table 2 below). The FCQ used was the standard course evaluation tool administered for all courses by the University, and includes the two open ended questions listed below where students are asked "*what was the most effective aspect of the course*" and "*what was the least effective aspect of the course*". The other questions are too generic to yield specific information on course topics.

Table 2. Summary of Student FCQ Comments on the Ethics Module of the Course

	Fall 2001	Fall 2002	Fall 2003	Fall 2004
# of FCQs returned	17	21	57	43
ethics listed as most effective course aspect	0	0	2	1
ethics listed as least effective course aspect	0	1	5	5

Project Module

The previous 3-week transportation lab module has been replaced with a three-week study of the Three Gorges Dam (TGD) in China. In the earlier transportation lab, students went outside to a local intersection and gathered real operational data by counting traffic volume and computing typical delay. It involved a write-up, calculations, and data presentation in graphs and tables. In the TGD project, students explore sub-topics that include both technical aspects of the project and its broader social, cultural and environmental impacts. Balancing these issues, the students then discuss whether or not they support the Three Gorges Dam project. Each student produces a slide on their sub-topic that they share with a smaller break-out group (eight to thirteen students, depending on the size of the class). Each student also creates a one to two page *Fact Sheet* on their sub-topic, which includes salient facts, tables, figures, pictures, and literature citations. The TGD project is broader and less detail oriented than the transportation lab. It also incorporates a greater diversity of the sub-disciplines of Civil Engineering. The project illustrates how multi-disciplinary teams are needed to tackle large and complex problems. Although a large project in the U.S., such as the "Big Dig" transportation project in Boston (http://www.massturnpike.com/bigdig/), could illustrate many of the same concepts, the TGD project in China has wider sweeping consequences. The TGD project also illustrates that many of the things that are taken for granted in the U.S., such as clean water, sanitation, and energy, are the result of engineering and aren't universally available.

Numerous students referred to the TGD project in their final course essays. For example, one student wrote: "The TGD project greatly influenced my decision to be a civil engineer. There are so many aspects that a civil engineer must consider when working on a project. There were 13 areas of discussion... from that one project. That was very exciting to me because this means more diversity of work...." Based on the write-in comments on the Faculty Course Questionnaires (FCQs) submitted by students at the end of the semester (Table 3), the TGD project was more popular than the transportation lab.

Table 3. Summary of Student FCQ Comments pertaining to the Projects

	Fall 2001 Trans Lab	Fall 2002 Trans Lab	Fall 2003 TGD	Fall 2004 TGD
# of FCQs returned	17	21	57	43
most effective aspect of course	0	1	8.5*	4*
least effective aspect of course	4	2	**	1, **

* some students just wrote "projects"; the TGD project was one of the two projects in the course (the other was West Point Bridge Designer), so each of these responses was counted as 0.5
** in 2003 one student wrote: formatting TGD fact sheet; in 2004 one student wrote "not seeing TGD slides"

Professional Society Meeting

Students are required to attend a meeting of an engineering professional society. Student chapters of the American Society of Civil Engineers (ASCE), the Association of General Contractors (AGC), the Society of Women Engineers (SWE), etc. hold meetings approximately every two weeks and frequently have practicing engineers as guest speakers. Over the past two years (2003-2004), 33% of the 94 students have chosen to attend the student chapter of Engineers Without Borders (EWB) (www.ewb-usa.org). EWB is non-profit organization started in 2000 by Civil Engineering professor Bernard Amadei of the University of Colorado (CU). The goals of the group are to help disadvantaged communities worldwide and develop internationally responsible engineers. Teams of students, professors, and professional engineers partner with the local community to provide basic infrastructure by studying, designing, and implementing water, sanitation, shelter, energy, transportation, etc. projects. The CU chapter, for example, is conducting water and sanitation projects in Haiti, Rwanda, and Peru. After attending the society meeting of their choice, students write a half-page essay describing the experience. A number of students indicated an interest in joining EWB. For example, one student wrote: "The meeting produced new inspiration for continuing my education in engineering, joining a society like EWB, and definitely going abroad to contribute to the world around me." Another stated: "I have decided to join EWB with the hope of bettering myself and the lives of those around the world." Over the entire group of 94 essays, 16% of the men and 27% of the women stated interested in joining an organization due to a desire to contribute to society.

Final Student Essay

At the end of the semester, students submit journals that include a reflective essay on why they want to be a civil engineer (or not). The instructions for the students are: "*Discuss why you do or do not want to be a civil engineer (based on your personal experiences prior to CU, content in this course, AND your other coursework). Give specific examples from these various experiences that have impacted your decision. State specific aspects of Civil Engineering and being a Civil Engineer that appeal and do not appeal to you.*" In these essays, 50% of 8 women and 21% of 84 men stated an interest in serving society. The projects and case studies in developing countries are particularly effective in demonstrating how civil engineering can impact people in life-and-death ways. Although societal impacts also occur in domestic projects, these aspects are sometimes overshadowed by economic and political concerns. One student in 2003 stated: "The main thing that this course told me about civil engineering is that there is a definite need for bright and responsible civil engineers everywhere in the world. One of the other things I like about civil engineering is that you are doing projects for the good of society."

Outcomes Evaluation

One potentially useful tool to evaluate the impact of curriculum changes is the Pittsburg Freshman Engineering Attitudes Survey (PFEAS)[4-6] (http://www.flaguide.org/tools/attitude/pitts_freshman_attitudes.php). The survey contains 50 questions that students respond to on a Likert scale from 5 (strongly agree) to 1 (strongly disagree). This survey was used for the first time in Fall 2004. It was administered on the first and last day of class. As shown in Table 4, the numbers of students who filled out the pre and post course survey were not the same. This is

due to a combination of reasons: some students dropped the course, some students added the course late, and some students did not fill in an ID number so it was not possible to determine if the student filled out both surveys. The responses to most questions showed little change before and after the course, based on paired t-tests in Excel, as shown in Table 4 below. Male, female, and minority students did indicate an increase in the feeling that they "know what an engineer does", with p values of 0.01, 0.10, and 0.02, respectively. This indicates that this course (in combination with the other courses that the students were taking in the Fall 2004 semester) successfully fulfilled one of its key goals. Interestingly, male students increased their confidence in their calculus, writing, and speaking skills, and decreased in the confidence in chemistry (a typical first semester course for engineering students). Female students did not indicate any significant changes in their attitudes towards the various skill sets. Male students decreased in their confidence in the adequacy of their study habits (based on significantly different responses to two questions), and female students also exhibited this trait although to a lesser degree (based on a significantly different response to only one question, "I am confident about my current study habits").

There were only small differences in the attitudes of male vs. female students, and male vs. minority students. Before the course, minority students disliked engineering more than typical male students, with lower response to "the advantages of studying engineering outweigh the disadvantages" and a higher response to "I can think of several other majors that would be more rewarding than engineering."

Table 4. Number of students who participated in the PFEAS and the number of the 50 questions where t-tests indicated significantly different responses

Category	Male Students	Female Students	Minority Students
number of students (n) who filled out the pre survey	50	6	13
n who filled out post survey	41	7	11
n who filled out both the pre and post surveys	34	6	10
paired t-test of pre vs. post responses:			
# of questions with significant difference at >95% confidence	8	0	6
# of questions w/ significant difference at 90-95% confidence	9	7	5
differences in pre attitudes vs. male responses:			
# of questions w/ significant difference at >90% confidence	NA	2	3
differences in post attitudes vs. male responses:			
# of questions w/ significant difference at >90% confidence	NA	4	4

A set of four questions on the survey probe students' perceptions of how engineers impact society. Example results are shown in Figure 1. Paired t-tests of pre vs post surveys indicated that male students significantly increased ($p = 0.06$) their agreement with the statement "Engineers contribute more to making the world a better place than people in most professions"; the agreement of minority students also significantly increased ($p = 0.08$). The students did not exhibit significant changes in attitude between the pre and post survey on any of the other three questions shown in Figure 1. The reasons why the impacts on the student attitudes were not as positive as desired are not known. However, making a significant change in student attitudes towards engineers' influences on society in a 1-credit course with other primary goals may be

overly optimistic. At the end of the course, minority students had a significantly higher ($p = 0.09$) response than male students to the question "technology plays an important role in solving society's problems." Other differences between men, women, and minority student attitudes were not statistically significant.

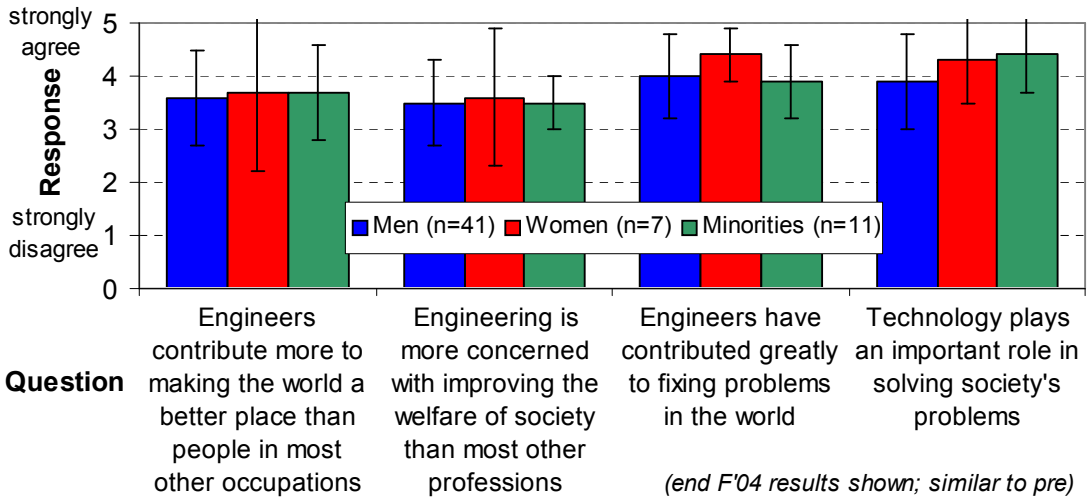

Figure 1. Student responses to PFEAS questions on the societal impacts of engineering

The PFEAS data was also sorted to look for differences between the attitudes of students in different majors. Given the small number of minority and female students in the class, this analysis was only done for the male students. Results are summarized in Table 5. The greatest differences in attitudes before the course were found between students enrolled as Civil Engineering (CVEN) majors vs students who were undeclared (open option) engineering majors or other kinds of engineering majors (in this case, 1 environmental engineering student). Differences were less pronounced when comparing engineering students to non-engineering students (most of whom, 7, were undeclared students in the College of Arts and Sciences). Of particular interest, on the pre test the CVEN majors responded significantly more favorably than other engineering majors to the last two questions (shown to the right on the x-axis of Figure 1) related to the perception of how engineers contribute positively to society ($p = 0.08, 0.04$).

Table 5. T-tests comparing the PFEAS responses of students from different majors

Category	Majors of Students Responding to the PFEAS Survey		
	CVEN vs other eng	CVEN vs non engrg	Engrg vs Non-Engrg
Pre Tests: n male students who finished the course	20 / 10	20 / 10	30 / 10
# questions w/ different responses where $p < 0.05$	11	6	6
# questions w/ different responses ($0.10 > p > 0.05$)	4	3	2
Post Tests: n male students who finished the course	19 / 12	19 / 10	31 / 10
# questions w/ different responses where $p < 0.05$	10	11	3
# questions w/ different responses ($0.10 > p > 0.05$)	3	5	4

Based on the post test, attitude differences between the CVEN students and non-engineering majors increased, given the larger number of questions on the post test where there were significant differences in these groups. In the post test, the responses of the engineering majors who were not CVENs and the non-engineers became more similar. The CVEN majors were more positive about engineering. The only difference in their perception of how engineers contribute to society was the significantly lower response of the non-engineers compared to engineering majors to the question "engineers have contributed greatly to fixing problems in the world" ($p = 0.02$). Perhaps appropriately, CVEN majors also responded higher on the questions "I feel I know what an engineer does" and "I feel confident in my ability to succeed in engineering", in comparison to other engineering majors and non-engineering majors ($p < 0.09$). This may indicate that the course is most effective for students who are already interested in CVEN; therefore, the course may be somewhat more helpful in retention of CVENs than in recruiting students into CVEN.

Future use of the survey over a longer timeframe and perhaps in the freshman introductory courses in the other majors may yield more useful information. In the future, other survey instruments may be used or developed to probe student attitudes and the impacts of curriculum changes.

Broader Efforts to Internationalize Engineering Curricula

An initiative in *Engineering for Developing Communities* (EDC) is underway at the University of Colorado (http://www.edc-cu.org/). The program includes courses, research, service, and outreach activities. A long-term goal is to create a certificate in EDC that undergraduate students could earn. This would be similar to other certificate programs, such as the Certificate in International Engineering in German (http://engineering.colorado.edu/academics/german_faq.htm). The changes in the freshman course would be an opportunity to spark student interest in the EDC program. Many other courses have also incorporated international aspects into the curriculum. Sections of the three-credit Freshman Projects course emphasize appropriate technologies for the developing world. Within the Civil and Environmental Engineering degrees, lectures have been added to address water and sanitation appropriate for rural areas and developing communities. Since 2001, some of the capstone design projects have also worked with international communities (http://www.colorado.edu/engineering/civil/CVEN4434/projects.html). A new two-semester long, 6-credit "Engineering for the Developing World" course with students across different engineering majors is being piloted for the first time in the 2005-2006 academic year by Professor Bernard Amadei. In past years, Prof. Amadei also taught a Sustainability course that included international aspects.

Summary and Conclusions

Small changes in the curriculum specifics of the 1-credit introductory civil engineering freshman course have incorporated international aspects. These changes were reasonably simple and did not require significant extra effort on the part of the course instructors. These changes appear to have been popular with students, and are particularly useful for emphasizing the role that engineers play in improving the quality of life of individuals worldwide. These helping aspects of the engineering profession are sometimes under-emphasized and may be attractive to some

students, helping to improve retention through challenging fundamental coursework that makes up the bulk of most freshman engineering coursework. As the University of Colorado continues to work toward offering an undergraduate certificate in Engineering for Developing Communities (EDC), the content in this course may help students identify if EDC is an area that they wish to pursue.

Acknowledgments

This material is partially based upon work supported by the National Science Foundation under Grant No. 0431947. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Bibliography

1. ABET. 2004. Criteria for Accrediting Engineering Programs. Effective for Evaluations During the 2005-2006 Accreditation Cycle. ABET, Inc. Baltimore, MD. www.abet.org

2. National Academy of Engineering. 2004. The Engineer of 2020: Visions of Engineering in the New Century. Washington DC. National Academies Press.

3. World Bank 2003. World Development Report: Sustainable Development in a Dynamic World: Transforming Institutions, Growth, and Quality of Life, Washington DC.

4. Besterfield-Sacre, M.E., Atman, C.J., and Shuman, L.J., Student Attitudes Assessment," Journal of Engineering Education, 87(2), April 1998, 133-141.

5. Besterfield-Sacre, M.E., C.J. Atman and L.J. Shuman, Characteristics of Freshman Engineering Students: Models for Determining Student Attrition and Success in Engineering," The Journal of Engineering Education, 86(2), April 1997.

6. Besterfield-Sacre, M.E. and C.J. Atman, "Survey Design Methodology: Measuring Freshman Attitudes About Engineering," American Society for Engineering Education Conference Proceedings, June 1994, pp. 236-242.