AC 2010-21: OUTREACH TEACHING, COMMUNICATION, AND INTERPERSONAL SKILLS ENCOURAGE WOMEN AND MAY FACILITATE THEIR RECRUITMENT AND RETENTION IN THE ENGINEERING CURRICULUM

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Outreach Teaching, Communication, and Interpersonal Skills
Encourage Women and may Facilitate their Recruitment and Retention in the Engineering Curriculum

Abstract

Women continue to be underrepresented in engineering and technology fields. Recent gains in gender equity in bioengineering and environmental engineering suggest that women are attracted to fields they view as contributing to society. Furthermore, it has been suggested that women’s choice to enter a particular field of engineering is related to their perceived strengths in areas such as communication and interpersonal skills. We incorporated an outreach teaching activity and emphasized communication and interpersonal skills in an undergraduate engineering course and found that women undergraduates had higher confidence than men in these areas and viewed these activities as most worthwhile for their career.

Structural Aspects of Biomaterials is an upper-level undergraduate course cross-listed with mechanical and bioengineering. The enrollment is typically about 50 students with an even gender split. The course emphasized outreach, communication, and interpersonal skills with a group project supported throughout the semester by a required skills lab. The project included an outreach teaching activity for 5th grade students at a local children’s science museum, a written report, and an oral presentation. The supporting skills lab taught technical writing and editing, oral presentation skills, and interpersonal skills linked to Felder’s learning styles. Student teams were assigned so that all majors, learning styles, and genders were represented in each team. The activities were assessed using four surveys throughout the semester.

Women undergraduates in the course ranked learning styles, teamwork, writing and presentation activities, and the outreach teaching activity more highly than men when asked what activities were most useful for their career. Interestingly, women also self-reported higher confidence than men in 7 of 11 of our learning objectives at the beginning of the semester, and 8 of 11 at the end of the semester. Areas of higher confidence for women included working and communicating effectively on a team with various learning styles and engaging the community about science. Areas of higher confidence for men included critically evaluating written and analytical work of themselves and others, and recognizing issues and technological advances in bioengineering.

Assessment of learning styles in this course revealed that women were slightly more verbal, sensing, and active, while men were slightly more visual, intuitive, and reflective.

Our results suggest that incorporating outreach projects and emphasizing communication and interpersonal skills appeals to women in undergraduate engineering programs. This course could be used as a model for first-year courses to recruit and retain women in engineering. Furthermore, the outreach activity not only allows engineering students to contribute to society, but exposes young K-8 women to engineering and role models.

Introduction

Women continue to be underrepresented in engineering and technology fields. According to data compiled by the National Science Foundation on women in engineering and science in 2006,
women accounted for 17% of undergraduates enrolled in engineering programs. In graduate studies, women accounted for 24% of full-time enrolled graduate students in engineering and 42% of full-time graduate students in all fields identified as science and engineering. In academia, women account for about 28% of full-time tenured or tenure-track faculty in science and engineering, and about 40% of those with recent doctorates. With respect to employment in business and industry, women account for about 35% of all scientists and engineers employed in business and industry, 19% of all managers, and only 10% of engineering managers.

A great deal of research suggests obstacles to women entering and thriving in STEM fields, such as: curriculum and pedagogy, a perceived lack of role models, an isolating and intimidating climate, early experiences, pressure to conform to traditional gender roles, and difficulty balancing life and family in a demanding, ever-changing field. A review of these obstacles by Blickenstaff lead to suggestions including: eliminating sexist language and imagery, equal access to pedagogical resources at all levels, an emphasis on depth rather than breadth, using cooperative rather than competitive groups mixing genders, and emphasizing “the ways that science can improve the quality of life of living things.”

Recent gains in bioengineering and environmental engineering support the idea that the field’s perceived contribution to society may outweigh and overcome some of these obstacles for women in engineering. Despite accounting for only 24% of all engineering graduate students in 2006, women accounted for 39% of graduate students in bioengineering, 32% in civil/environmental engineering, and 34% in agricultural engineering. Similarly, in business and industry, women accounted for over 60% of medical and health services managers compared to only 10% of engineering managers. As the numbers of women in these fields increase, the climate is likely to be less isolating and intimidating, and provide more role models. Also, these fields are more in line with traditional gender roles for women as care-takers. In a study by Baker and Leary on the attitudes of girls in primary and secondary grades toward science, they found a common more positive attitude towards life sciences explained by the girls as a common desire to care for people and animals.

It has also been suggested that women’s choice to enter a particular field of engineering is related to their perceived strengths in certain areas, such as communication and interpersonal skills. Women in engineering often report lower confidence in science and math skills than men despite higher or equivalent grades, or women’s confidence and performance decrease throughout an engineering program. However, women are often perceived to have better communication and interpersonal skills, but these so-called “soft skills” are not as emphasized in engineering curricula as the math and science “hard skills.”

Keeping in mind these obstacles, recent gains, and perceptions, we incorporated an outreach teaching activity and emphasized communication and interpersonal skills in an undergraduate engineering course to enhance the educational experience for all students, and particularly for women students.

**Course Structure**
Structural Aspects of Biomaterials is an upper-level elective course listed in both the mechanical and bioengineering departments at a large public research university. Topics include material properties, mechanical behavior, and clinical significance of biological tissues and the metals, ceramics, and polymers used in medical devices. The FDA, patent law, and ethical considerations are also part of the course material. Structural Aspects of Biomaterials has been taught for nearly a decade and in this timeframe, the course has evolved from a survey course to a course with emphasis on project-based learning, interdisciplinary problems, communication and interpersonal skills, and outreach teaching.

At the beginning of the semester we presented the following learning objectives: at the end of this skills lab, students will be able to...

**Technical Communication and Teamwork**

- operate and communicate effectively on a multi-disciplinary team with a variety of learning and personality styles.
- effectively communicate technical information in written and oral settings.
- critically evaluate the written, oral, and engineering analysis work of themselves and others by identifying the strengths and areas for improvement.
- assess the value of work from various sources such as the internet and peer reviewed journals.

**Teaching and Learning**

- describe the importance of engaging the community in a discussion of science through outreach teaching.
- create a museum exhibit to demonstrate a complex engineering concept to non-technical audience with various learning styles.
- identify his or her dominant learning style and develop strategies for enhancing skills in the other learning styles.
- adapt their teaching and communication to address multiple learning styles.
- identify levels of Bloom’s taxonomy in HW and test questions and in project deliverables.

**Putting engineering biomaterials in larger context**
- evaluate biomechanical designs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, and manufacturability.

- recognize contemporary and historic bioengineering issues and technological advances, and their impact in a global, economic, environmental, and societal context.

The course enrollment is typically about 50 students with a relatively even split amongst genders and majors. This particular year the enrollment was 48 students: 23 female, 25 male; 17 mechanical engineering students, 31 bioengineering students; 42 juniors and seniors, 6 graduate students.

The semester-long course was taught with two 90-minute lectures each week covering the fundamental mechanical and biological course material through traditional lectures, in-class activities, guest lectures, and case studies. In addition, students were required to attend a skills lab for two hours once a week covering a limited review of mechanics, learning styles, group dynamics, outreach teaching, Bloom’s taxonomy, assessment rubrics, library skills, technical writing and editing, and oral presentations (Table 1). Students were assessed based on two midterm exams and a final group project comprising a written report, an oral presentation, and an outreach teaching activity at a local children’s science museum. The grades were assigned based on 25% for each of two exams, 10% assignments, and 40% final project.

This course’s unique emphasis on outreach teaching and on communication and interpersonal skills was enacted primarily through the skills lab and the final group project. The common theme around which these activities were built was Felder’s learning styles. In the skills lab, students began the semester by identifying their learning styles with Felder’s online assessment tool (active vs. reflective; intuitive vs. sensing; sequential vs. global; visual vs. verbal). The concept of learning styles was discussed in the skills lab and incorporated into assignments and activities.

For the final project, groups of three to five students were assigned so that all majors, learning styles, and genders were represented as evenly as possible in each group. Students were then asked to consider their group members different learning styles and backgrounds as they worked together. The final project deliverables also required students to consider various learning styles as they produced their final written report, oral presentation, and outreach teaching activity.

The outreach teaching activity provided an opportunity for the students to use their engineering knowledge to contribute to society on a local scale by interesting children in science and engineering. The outreach project, entitled “Body by Design”, was administered in collaboration with a local children’s science museum and a 5th grade elementary science class. The groups were assigned a specific medical device with the task of teaching a technical concept associated with the medical implant to the 5th graders using an interactive scientific exhibit that addresses all the various learning styles.

The emphasis on outreach teaching and on communication and interpersonal skills was assessed using surveys at four points during the semester. Each survey asked questions about the usefulness of the skills lab activities and the final project. The students gave informed consent to participate in the surveys at the beginning of the semester, and used an anonymous code so that we could track individual answers over time without knowing the identity of the survey.
respondents. Protocols for the informed consent and data collection were approved by the campus Committee of Protection of Human Subjects. The final survey is included as an appendix.

<table>
<thead>
<tr>
<th>Table 1: Skills labs topics in chronological order</th>
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<tbody>
<tr>
<td>Mechanics review</td>
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<tr>
<td>Learning styles</td>
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<tr>
<td>Team building</td>
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<tr>
<td>Bloom’s taxonomy</td>
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<tr>
<td>Library workshop</td>
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<tr>
<td>Technical writing</td>
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<tr>
<td>Oral presentation</td>
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<tr>
<td>Editing writing</td>
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<tr>
<td>Exhibit feedback</td>
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<tr>
<td>Group work</td>
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</tbody>
</table>

**Results**

The demographics of the course show a relatively even gender split (Figure 1), with slightly more women students in bioengineering (17 women vs 14 men) and more men students in mechanical engineering (6 women vs 11 men).
Figure 1. Demographic breakdown of genders and majors in the course showing almost equal numbers of men and women students, with slightly more women in bioengineering and fewer women in mechanical engineering.

The results were remarkably similar for women and men students with respect to their plans after graduation, with about 60% of students planning to attend some type of graduate school, and 40% planning to go directly to a job in industry (Figure 2).

Figure 2. Response to the question: At this point, what are your plans after school here? Women’s and men’s responses were very similar.

When it came to a preference for working in a group or individually, women students reported slightly less preference for entirely individual work, while men students reported slightly more
preference for working entirely in a group. Women students were more likely to report working equally well in a group or individually (Figure 3).

![Circular diagram showing preference for working in groups, individually, or equally. Women preferred working individually (41%), equally (36%), and in a group (23%). Men preferred working in a group (50%), equally (21%), and individually (29%).]

Figure 3. Responses to the question: Do you prefer working on projects more in a group or individually? Women preferred exclusively individual work a bit less.

Women undergraduates in the course exhibited a trend of ranking learning styles, teamwork, writing and presentation activities, and the outreach teaching activity more highly than men when asked what activities were most useful, particularly for their career (5 of these statistically significant at p<0.1, shown in Figure 4). Women undergraduates also tended to be more likely to recommend the course to their engineering friends (p<0.12) (Figure 5).

Interestingly, women self-reported higher confidence than men in 7 of 11 of our learning objectives at the beginning of the semester and 8 of 11 at the end of the semester (8 of these comparisons between women and men significant at p<0.1, as shown in Figure 6). Areas of higher confidence for women included operating and communicating effectively on a team with various learning styles and engaging the community about science. Areas of higher confidence for men included critically evaluating written and analytical work of themselves and others, and recognizing issues and technological advances in bioengineering. Both women and men reported higher confidence in all areas at the end of the course compared to the beginning (p<0.01, paired t-test).
What skills labs do you think will be the most useful for....?
(Rank from 1 to 10, 10 = most useful)

Figure 4. Average response to the question: What skills labs do you think will be the most useful for this course, other courses, your career? (* indicates p<0.10)

Figure 5. Responses to the question: Would you recommend this course to a friend? Women were more likely to recommend the course (p<0.12).
Figure 6. Average response to the question: How confident are you in the following learning objectives? (* p<0.1, ** p<0.05, all comparisons of beginning confidence to end p<0.01)
With respect to learning styles, in this course women were slightly more verbal, sensing, and active, while men were slightly more visual, intuitive, and reflective (Figure 7).

Figure 7. Learning styles broken down by gender: women were generally more verbal, sensing, and active.

Conclusions

Our results suggest that incorporating outreach projects and emphasizing communication and interpersonal skills appeals to women in undergraduate engineering programs. In this course, women had higher confidence than men in the areas of outreach teaching and communication and interpersonal skills, and tended to view these activities as most worthwhile for their career, as evidenced by Figures 4 and 6. Women were also more likely to recommend the course to a friend in engineering, shown in Figure 5.

Contrary to other studies, women in this course reported higher confidence than men in most of our learning objectives both before and after the course (Figure 6). The exceptions (where men reported higher confidence) were critically evaluating written and analytical work, and recognizing technological advances in bioengineering. It is important to note our learning objectives were specially focused on communicating effectively, working on a team, and engaging the community about science, and the learning objectives were consciously presented to the students under these headings at the beginning of the semester. Our results suggest that incorporating and transparently emphasizing these skills might help build confidence of women in engineering courses.
Compared with men in the course, there was a trend of women identifying communication, teamwork, and outreach teaching activities as more important for their career (Figure 4). The fact that more women found these types of activities as more useful may also be related to the learning styles represented by more women. Women tended to be more verbal, sensing, and active, as evidenced in Figure 7. Individuals with a more verbal learning style may find writing activities more useful, while individuals with a more active learning style may find the activity of putting together a museum exhibit and participating in outreach teaching more useful than reflective learners. It is also important to note that there were more bioengineers in the course this year (Figure 1), and the students that choose bioengineering as a major may be more receptive to some of these activities regardless of gender. However, women and men reported almost identical career plans (Figure 2), so it is unlikely that differences were due to perceptions of what skills are important in their future career (graduate school versus industry).

These results also show activities that women considered useful for their future career. As instructors, we consciously emphasized how all of the skills we taught could be used beyond this particular course. We also discussed broad applications of the course content including patent law and working for government regulatory agencies such as the FDA. In a future iteration of this course, it would be interesting to further probe the affect of emphasizing broad future applications of skills on both men and women.

In retrospect, more accurate conclusions could be drawn if we had organized and worded the survey questions differently. This is our first year attempting to formally evaluate the course using surveys, and our observations will be used to help us form survey questions that can best answer our hypotheses. For example, the learning objectives as phrased were detailed and overlapping in skills, such as “operating and communicating effectively in a team.” In the next iteration, we will ask about distinct separate skills, such as “teamwork,” “written communication,” “oral communication,” “critical thinking,” “problem analysis,” etc. We also did not obtain consent to use the students’ grades, so we were unable to determine perceived confidence versus actual mastery.

Additionally, we were unable to provide rigorous statistical comparisons given the relatively small number of students and the simple ordinal scales used for the survey questions. The responses of women versus men in this paper were compared using simple student t-tests, using a generous significance level of p<0.1 to detect trends. A pairwise t-test was used to compare the before versus after responses of students’ confidence in the course objectives. Despite the statistical limitations, trends were identified that point toward future research questions. We look forward to participating in the field of engineering education to get ideas and feedback on our assessment tools and approaches.

This unique course has many benefits. From the perspective of an engineering department, the emphasis on teamwork and communication skills meets several ABET criteria. For women undergraduates in engineering, it emphasizes broad skills that help build women’s confidence in engineering, provides an opportunity for women engineers to contribute to society, and emphasizes future career applications of engineering skills. With respect to recruiting more underrepresented students into engineering, the outreach activity exposes young K-8 women and minorities to engaging engineering activities and to diverse engineering role models.
Although the evaluation of this course is in a preliminary stage, our observations suggest that this course could be a model to recruit and retain women in engineering. First year introductory courses could incorporate these activities to encourage more women undergraduates earlier in the pipeline. In particular, emphasizing the importance of communication and interpersonal skills while providing an opportunity to connect engineering to society through outreach activities appear to be worthwhile and confidence-building for women undergraduates.

References


Appendix – Final Survey

BioE/ME C117 Structural Aspects of Biomaterials
Course Survey IV
May 6, 2009
Birthday (mm/dd) + first letter of street on which you live (please enter the same code you used for the first survey):

1. Are you an undergraduate or a graduate student?
   a) Undergraduate  b) Graduate  c) Other (Explain):

2. What is your major?
   a) Mechanical Eng.  b) Bioengineering  c) Material Science  d) Other: _______________

3. What is your gender?
   M  F  Other

4. Where do you feel you generally learn most of the material related for THIS course? Please rank the following components from 1-5, where you learn the most from #1.
   a) Lecture  b) Discussions  c) Homework  d) Exam Studying  e) Class Projects

5. What activities do you feel best helped you prepare for the LHS activity? Please rank the following items that are relevant (#1 helped the most, leave it blank if it does not apply).
   a) Lecture  b) LHS overview during skills lab  c) Meeting with the GSIs
   d) Feedback from Craig and John Michael  e) Visiting LHS (on your own)
   f) Learning styles  g) Bloom’s Taxonomy
   h) Previous experience with kids  i) Prototyping with your group

Additional comments or explanations:

6. What activities do you feel best helped you prepare for the final project? Please rank the following items that are relevant (#1 helped the most, leave it blank if it does not apply).
   a) Lecture  b) Homeworks  c) Exams
   d) Literature searches  e) Outside mechanics books (ie, on reserve)
   f) Oral presentation skills lab  g) Technical writing skills lab
   h) Peer-editing activities  i) Learning styles  j) Bloom’s Taxonomy

Additional comments or explanations:

7. What skills labs do you think has been the most useful for this course? Please rank the following from 1-10, where #1 was the most useful.
   a) Group review of mechanics  b) Learning styles  c) Paper/straw activity w/ LHS staff
   d) Bloom’s Taxonomy  e) Library workshop  f) Technical writing lab
   g) Oral presentation skills  h) Editing writing  i) LHS  j) Group work (final projects)
8. What skills labs do you think will be the most useful for other courses? Please rank the following from 1-10, where #1 was the most useful.

   a) Group review of mechanics  
   b) Learning styles  
   c) Paper/straw activity w/ LHS staff  
   d) Bloom’s Taxonomy  
   e) Library workshop  
   f) Technical writing lab  
   g) Oral presentation skills  
   h) Editing writing  
   i) LHS  
   j) Group work (final projects)

9. What skills labs do you think will be the most useful for your career (or life in general)? Please rank the following from 1-10, where #1 was the most useful.

   a) Group review of mechanics  
   b) Learning styles  
   c) Paper/straw activity w/ LHS staff  
   d) Bloom’s Taxonomy  
   e) Library workshop  
   f) Technical writing lab  
   g) Oral presentation skills  
   h) Editing writing  
   i) LHS  
   j) Group work (final projects)

10. What are your thoughts about the groups that were formed and how they have worked so far? Check all that apply.

   a) Having opposing learning styles brings new and creative ideas to our discussions  
   b) Having opposing learning styles has hindered our discussions  
   c) The opposing learning styles make it difficult to work together effectively and come to agreement  
   d) I can recognize our different learning styles and how it plays into our group discussions  
   e) I haven’t noticed a difference among my group members in terms of how they learn or contribute ideas

11. Do you feel you have unique ideas and skills to offer your group? Y/N, explain (if additional or different from previous surveys).

12. How much work do you feel you do for the group compared to others in your group? (circle one)

   a) A lot more  
   b) A little more  
   c) About the same  
   d) A little less  
   e) A lot less

   Why do you feel this is the case? (i.e., more/less background knowledge, more/less time available, more/less concern for grade, etc.)
13. Revisiting our learning objectives, how confident are you in the following areas (1 = not very confident at all, 5 = extremely confident), both at the beginning of the class, and now.

<table>
<thead>
<tr>
<th>LEAST CONFIDENT</th>
<th>MOST CONFIDENT</th>
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</thead>
<tbody>
<tr>
<td>a) operate and communicate effectively on a multi-disciplinary team with a variety of learning and personality styles</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
</tr>
<tr>
<td>b) effectively communicate technical information in written and oral settings</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
</tr>
<tr>
<td>c) critically evaluate the written, oral, and engineering analysis work of themselves and others by identifying the strengths and areas for improvement</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>d) assess the value of work from various sources such as the internet and peer reviewed journals</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
</tr>
<tr>
<td>e) describe the importance of engaging the community in a discussion of science through outreach teaching</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
</tr>
<tr>
<td>f) create a museum exhibit to demonstrate a complex engineering concept to non-technical audience with various learning styles</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>g) identify your dominant learning style and develop strategies for enhancing skills in the other learning styles</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>h) adapt your teaching and communication to address multiple learning styles</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>i) identify levels of Bloom’s taxonomy in HW and test questions and in project deliverables</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>j) evaluate biomechanical designs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, and manufacturability</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
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<tr>
<td>k) recognize contemporary and historic bioengineering issues and technological advances, and their impact in a global, economic, environmental, and societal context</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>at the beginning:</td>
<td>now:</td>
</tr>
</tbody>
</table>
14. What are three things you remember most/ will take with you from skills lab?
   1) 
   2) 
   3) 

15. What was the most enjoyable activity in skills lab? Why?

16. What was the least enjoyable activity in skills lab? Why?

17. What was the most useful activity in skills lab? Why?

18. What was the least useful activity in skills lab? Why?

19. Would you recommend taking this class to your friends? What advice would you give them?
   (1 = would not recommend, 5 = would definitely recommend)
   
   1  2  3  4  5

20. Do you have any suggestions, concerns, or comments about the skills lab? In particular, is there anything we should do more of, keep the same, or do less of next spring in this class?

________________________________________