The Benefit of Outreach to Engineering Students

Melissa Pickering, Emily Ryan, Kaitlyn Conroy,
Brian Gravel, Merredith Portsmore
Tufts University

Abstract

Engineering K-12 education outreach programs provide a unique opportunity for undergraduate engineers to develop communication and leadership skills as well as build self-confidence. Recently, there has been an engineering education outreach surge at many universities across the country. While the main goal of these programs is to assist educators in incorporating engineering into the K-12 curriculum, there are offshoot benefits to the undergraduate students who participate in outreach efforts, especially females. Capitalizing on a student's fresh engineering knowledge and young ambitions to make an impact, outreach programs send undergraduates into K-12 classrooms to introduce the engineering discipline to young children. Female engineers demonstrate a large interest in these outreach efforts, and subsequently enhance their overall undergraduate engineering experience. Beyond the initial self-satisfaction of working with young children, which gratifies the female instinct, the young women engineers are able to gain a greater confidence in the technical discipline that is often difficult to obtain in the male-dominated college classroom environment. Tufts University offers this opportunity through the Center for Engineering Educational Outreach, and in the following paper, the participating female engineers account their enhanced leadership, communication, and technical skills as a direct result of outreach.

Introduction

As technology becomes increasingly important in the global community, there is an ever growing need for technological literacy amongst the population. Integrating engineering with education on the K-12 level will foster the development of students' technological literacy; a valuable skill in becoming a global citizen. Engineering outreach is, thus, required in all societies to educate all people on the importance of engineering and the role it plays in society. A great deal of outreach stems from the university environment, and at Tufts University, outreach is a significant component of the School of Engineering.

The Center for Engineering Educational Outreach (CEEO) at Tufts University is dedicated to increasing people's knowledge and awareness of, and comfort with, technology and engineering. The work to complete this mission centers around 3 main areas:

1) Research - learning how children and teachers learn engineering

2) Development - activities, curricula, and tools for learning engineering
3) Education and support – professional development for educators, classroom support and web based support

The CEEO's major successes range from the development of ROBOLAB software (which has sold 25,000 copies world wide) to helping implement Massachusetts Engineering/Technology standards. The CEEO has worked for several years developing activities and tools that give K-12 students the opportunity to engage in hands-on engineering in the classroom. Activities employ a range of materials and tools – from simple paper clips and coffee filters to programmable LEGO bricks and sensors to power tools, wood, and metal. All activities aim to give students a chance to engage in authentic hands-on design, where they can create whatever they design. (Activities are detailed at www.ceeo.tufts.edu).

The two main issues implementing these activities in educational settings is making sure the educator understands the engineering and science concepts behind the activities and the logistical issues surrounding 25 students building and designing. The two ways the CEEO has been working to address these issues is through teacher professional development and by having undergraduate and graduate engineering students provide classroom support. The CEEO has hosted a number of workshops that have helped educators gain an understanding of engineering and how it can be used in a K-12 classroom. However, many are still nervous about introducing it into their classroom and concerned over the logistics of such an endeavor. In addition, many teachers are interested in implementing engineering but are unable to attend professional development workshops ahead of time. Engineering students are a great resource for providing support for educators before and after professional development. Whether they act as an extra set of hands to help build water filtration systems, or as a resource on whether an escalator contains pulleys or gears, or the person who takes the time to research when the first suspension bridge was built in Massachusetts, they provide educators with a safety blanket to encourage engineering education in the K-12 environment.

The CEEO has two programs that place engineering students in the classroom, both of which have been very popular and successful to date. The two programs, Tufts Engineering the Next Steps (TENS) (An NSF funded GK-12 project) and the Student Teacher Outreach Mentorship Program (STOMP), employ different models for their structure and allow for different levels of commitment. Participants in both programs work with educators to design activities and to help implement them in the classroom. They work outside the classroom doing background research and developing worksheets and resources. The engineering students often play a very active role in instruction, helping to explain concepts and demonstrate technologies, until the educator is comfortable taking on those responsibilities. Projects developed by engineering students range from a unit on Egyptians as Engineers, where students built LEGO vehicles to pull heavy "stone" blocks up an inclined plane, to teaching fluid velocity gradients to 4th graders with each student acting as a water molecule moving down a school's hallway.

The GK-12 program selects graduate engineering students to work in classrooms 10 hours a week in lieu of a research assistant position. They are provided full tuition and a monthly stipend for their participation. The program also includes an undergraduate staff who spend an abbreviated amount of time in the classroom (typically < 5hours) and work to support the graduate students by developing and testing activities for use in schools. On top of their 10 hours in the classroom, graduate students meet for two hour weekly seminars on education and teaching. They are also responsible for keeping journals about their activities and experiences and helping to collect research data. TENS GK-12 is integrated with the Education Department at Tufts and thus fellows gain a thorough understanding of education. The program is tremendously powerful because of the number of hours the graduate students can commit and because they are in the same classroom for a minimum of one year and often longer.

STOMP pairs engineering students with educators for 3-5 hours per week. The participants in STOMP are paid hourly and the program is structured more like a job. In contrast to GK-12, with shorter time blocks, and more undergraduate students, STOMP typically places students in a classroom for one semester at a time. STOMP also supports informal education settings like after school programs and robotics clubs. The educators and programs who work with STOMP often are on a 6-8 week project rotation that they need help developing or supporting. In addition to working in a classroom each week, STOMP fellows attend one hour semi monthly meetings to further their understanding of the educational process and how to work with students. A secondary part of STOMP's mission is to promote citizenship in engineering students in the hope that when they join industry they will have an understanding of the education system and the need for industry and engineers to take an active role. Initially founded by the LLL foundation, STOMP is committed to becoming self sustaining and those involved take an active role in looking for ways to fundraise for the program.

The interesting phenomenon the program directors have noticed about both programs is that they attract and retain a high percentage of female engineering students. While Tufts has a higher percentage of female engineering students (32%) than the national average (18%), the percentage of females in the CEEO's outreach programs exceeds this and ranges from 40 to 60% [1, 2]. The dropout rate in both programs is fairly low (5-10%) but it is even lower among females (3-7%).

Women have made great strides entering fields that were once heavily dominated by men; however, engineering remains a male-dominated college major and profession that women have been reluctant to enter (National Center for Education Statistics, 1997). When the statistics of women in engineering programs are compared to the 'traditional' engineering curriculum, one focusing heavily on specific technical objectives with little integration of social relevancy, reasons for the lack of women in engineering become more apparent. Critiques of teaching in math and science show these traditional pedagogical methods are ineffective at pulling women into the field.

The work of Tobias (1990) identifies problems for women such as too narrow a focus, a lack of application, and missing context [3]. Rosser (1990) suggests a number of inclusionary methods for teaching science, math, and engineering that include connecting women's life experiences to the subject matter, exploring fewer military problems and more problems "of social concern," and describing the global, holistic contexts of problems being solved in class, using interdisciplinary and interactive approaches to teaching [4]. Previous work suggests that women (and many men) may benefit from seeing explicitly how engineering can be used in careers that are personally satisfying and socially relevant. Indeed, it is ironic that many students (and the public) do not see engineering as socially relevant when it is the very purpose of the field to employ knowledge of math and science to solve problems faced by society.

Given the number of women in outreach at Tufts University's CEEO and the national trend in female engineering recruitment and attainment, a number of questions arise. Namely, "What draws people to outreach?", "Why do women, in particular, pursue outreach?", and "What benefits do engineering students receive from working in K-12 outreach?" It is postulated that outreach provides the social relevance and confidence-building environment typically missing in traditional academic engineering settings. To answer these questions, we undertook a pilot interview and survey process that is detailed in the following sections.

Methods

The data for this paper was obtained through a semi-structured interview and a survey of twenty-three engineering students involved in outreach. Thirteen of the students are male and ten are female. Eleven of the students work with the NSF GK-12 program and twelve students work with the STOMP program. The students cover all disciplines of engineering offered at Tufts and range from freshman to graduate students. The video interview contained thirteen questions that addressed the students' experiences in outreach and how it impacts their engineering skills. Additional questions about their background were also asked, such as how and why they became involved in outreach, and why they decided to become an engineer.

The survey consisted of eight questions dealing with the impact of outreach on the students' lives. Students were asked to rate the level and type of impact that outreach had on different areas of their lives such as communication skills, presentation ability and self confidence. The scale used for rating the impact ranged from negative five to positive five, with negative numbers indicating a negative impact, positive numbers a positive impact and zero indicating no impact. A sample of the survey and the interview questions can be found at the end of this paper (Appendix A).

Results and Discussion

Summary of Data

The quantitative survey data (Table 1) indicates that outreach has a greater impact on female engineering students than males. Survey results in the areas of leadership, engineering concepts, confidence, and confidence in engineering skills showed that females felt these areas were more significantly impacted than males. The results surrounding more general issues of communication skills, presentation, and time were fairly similar for both males and females. Communication skills were rated by both genders as the skill that outreach had the greatest impact on.

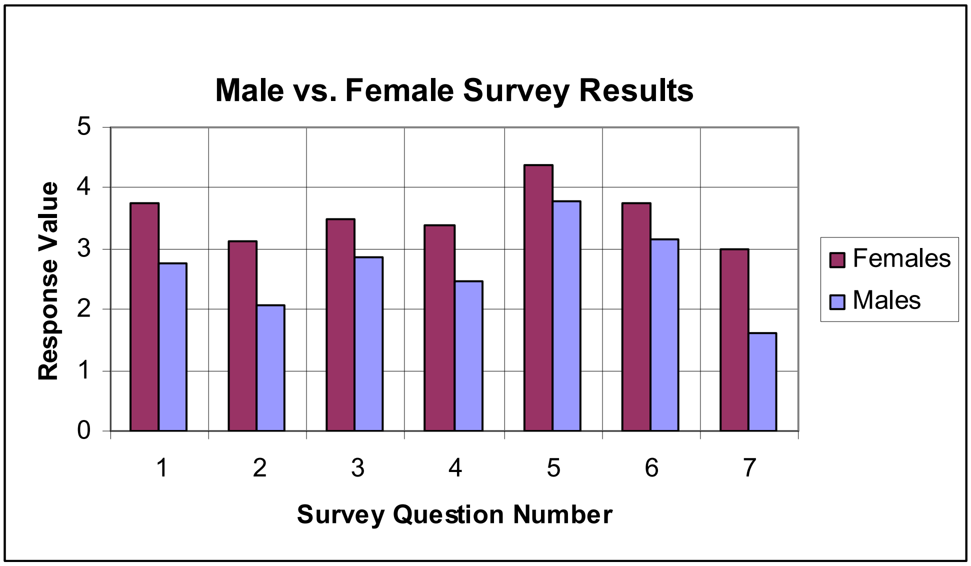

Table 1: Averaged Survey Responses separated by gender.

The semi structured interview gave more insight into why students choose to do outreach. The interviews illustrated that that many of the reasons for choosing and continuing with outreach were similar for males and females. The areas where differences occurred were around issues of social relevance and concern for the well being of others.

General Interest in Outreach

The interviews revealed that Tufts engineering students became interested in outreach for various reasons. Many undergraduates and graduates expressed an interest in teaching, but since the education classes did not fit with the rigorous engineering schedule, they pursued an outreach program in which they could combine two of their interests: engineering and education. The females interviewed cited more interest in helping children and getting engineering into the K-12 curriculum in order to show students what engineers are and what they do. One undergraduate explained that she did not even know what engineers did until she was a junior in high school and started looking at colleges. In this way Tufts engineering students feel a need to get engineering into the classroom and have found that the best way to do this is through outreach programs.

Once undergraduates and graduates have become involved in outreach many wonder why they don't change to research or another field of interest which may pay more or be more related to their job later on. Responses in the interviews indicated that undergraduate and graduate students enjoy the freedom and versatility of the outreach program. The ability to research any topic and present it in the classroom was mentioned by several students as a factor in keeping their interest. A majority of the interviewees explained that the interaction and impact they had on the children is what keeps them participating in outreach.

"I really like the kids. It's very rewarding to see them learn something and have a good time while they do it. The look on the kids faces when you pull out the Legos, and they can play with them and learn at the same time. I was hooked right then."

Getting kids excited about being in school was imperative to the college students who reminisced about their days in elementary, middle, and high school when they were not very interested in what was being taught.

"I remember when I was in school and there wasn't anything I was really intrigued by. The fact that these kids start working as soon as you walk in the door and just keep going until they run out of time. That's the most rewarding part of this program."

Another rewarding factor of these outreach programs is seeing the kids get excited, creative, and build something that works; particularly when they have invested their own time and thought, as the results show. The students' reaction to their inventions can be the most rewarding,

"…to see a kid with their eyes all wide sit and work, because he is interested not because he was told to work. Or to see a kid change from not wanting to do anything in a traditional math or science classroom to reaching out their hand and starting to do something, I think that's the most exciting aspect."

One female undergraduate commented on helping the students become more interested in math and science,

"…it feels as though most times in school [math] is taught as more of a boring subject. This outreach program is showing another aspect of math and science, and students who don't think they're good at math can see how they can apply it to the real world."

When the K-12 students are able to apply the engineering principles they have learned to their project, the university students expressed feelings of accomplishment.

The undergraduates and graduates also expressed that aside from feeling good about the impact they have made on students that outreach also helps them build important skills. Communication was mentioned the most in interviews as the skill that working in the classroom with K-12 students and teachers helped the engineering students to develop. The engineering students cited how the need to communicate to a non-technical audience forced them to examine their approach and explanations.

"Working with people who do not have the same level of technical training means that you have to explain things better. You can't assume knowledge that isn't there. Teaching in a classroom makes you aware that if you use technical terms you will not make any sense to the students, so you have to break it down for them."

The experience of outreach also helped students to work through problems and think on their feet. As one undergraduate explained, *"This experience helped me troubleshoot problems, because when you have a classroom of kids staring at you, you have to get things working."*

The development of communication skills is a major benefit for outreach participants as they prepare to enter into the world of engineering more confident and with more leadership skills. Communication with the director at the center, the school administration, the teachers, and with the students are all vital aspects of the outreach experience. These useful skills in human interaction are not included in the engineering curriculum, and undergraduate as well as graduate students must learn these skills elsewhere. Female undergraduates and graduates found this outreach program particularly helpful and expressed an interest in continuing with outreach activities.

Women in Outreach

Females often represent a minority in engineering in both academia and industry. One interviewee expressed,

"It's only me and four other girls in my classes, and those odds are good compared to my summer internship where I was the only girl in my section of cubicles."

Being a minority in such a situation presents an intimidation factor that the minority must face. Intimidation may inhibit a female's development of leadership and self-confidence as it is convenient for one to fall behind the shadow of the majority. However, through outreach opportunities, the female engineering students at Tufts are able to step ahead of this shadow and lead classrooms in engineering-related projects. This leadership experience enhances the female's portfolio, but more importantly builds self-confidence. The females are able to incorporate coursework knowledge into their outreach lessons, and subsequently gain confidence in their own understanding of the material. Being able to teach a concept involves a solid understanding of the concept itself. For example, one of the outreach participants expressed,

"I had no idea that I would have such a thorough understanding of gears as I do now, after waving my hands in the air for a demonstration in front of 4th graders."

In a K-12 classroom, the participants are authority figures on whom the pupils focus their attention, admiration, and respect. The survey data on increased core engineering curriculum knowledge and individual confidence indicates that the Tufts female engineer returns to the college classroom with a stronger knowledge base and increased confidence. In addition, she has a unique experience to share with peers. Gains in self-assurance may support the Tufts female engineer through the remainder of her college years, and subsequently sustain a rising trend in female engineering.

Conclusions

The data presented here show that outreach plays a valuable role in the engineering education of graduate and undergraduate students at Tufts University's Center for Engineering Educational Outreach. Students enjoy working with children and providing an opportunity to share the academic track they've chosen with others. Creating an excitement around learning engineering on the K-12 level diversifies and enhancing the overall education experience of both graduates and undergraduates. Outreach may play a more important role in appealing specifically to female engineers. As Rosser (1990) suggested, connecting life experiences to subject matter in engineering and increasing the social relevance of the curriculum helps to attract and retain women in the field. Other research has established that students' pursuit of an engineering degree can be related to their academic backgrounds [5,6], self-confidence or self-perceived ability in math and science [7-9], and aspirations and goals [5]. When comparing these findings to the nature of outreach work, it is concluded that the programs defined here (GK-12 and STOMP) add the social relevance aspect of engineering to the graduate or undergraduate career. Working with students and conveying the importance of engineering to society provides female engineers with the real-world connection that many have reported helps retain women in technical fields. In addition, these data suggest a higher confidence level regarding content; another factor linked retaining women in engineering. Therefore, our results suggest that the outreach programs available through the Center for Engineering Educational Outreach provide opportunities to not only spread engineering knowledge to the K-12 world, but to attract and retain women interested in connecting their academic endeavors with societal needs.

The results here are merely preliminary and suggest further work is needed to investigate the precisely what about outreach is appealing and what other factors may contribute to retaining high percentages of women in engineering. Larger sample sizes and more general qualitative data can hopefully decipher the specifics of outreach work that are attractive to all students and the effect these aspects have on the academic career and students' general satisfaction with receiving an engineering degree. Comparative studies are also needed to see how females in outreach program differ from those who are not engaged in outreach as well as longitudinal work on how the impact of outreach is sustained over time. These findings are promising and open the door for discovering the link between outreach and enhancing engineering education at the college level.

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Biographical Information

MELISSA PICKERING
Melissa Pickering is a junior at Tufts majoring in mechanical engineering. She has been part of STOMP since its inception and was selected to be a member of the executive board. She also is a leader in SWE and ASME and has written grants to fund local outreach programs.

EMILY RYAN
Emily Ryan is a senior at Tufts University majoring in mechanical engineering with a minor in astronomy. She has been involved with the GK12 program for four years. She is also an active member of ASME and ASCE.

KAITLYN CONROY
Kaitlyn Conroy is a sophomore at Tufts majoring in Civil Engineering. She started STOMP her freshman year and was selected to be a member of the executive board her sophomore year. She also participates in other campus activities including SWE, ASCE, and the Leonard Carmichael Society (volunteer organization).

BRIAN GRAVEL
Brian Gravel is the GK-12 Program Manager for the Center for Engineering Educational Outreach at Tufts University. He received his B.S. and M.S. in Mechanical Engineering from Tufts University and has presented at ASEE and FIE for the last 2 years.

MERREDITH PORTSMORE
Merredith Portsmore is the Education & Technology Program Coordinator for the Center for Engineering Educational Outreach at Tufts University. She received her B.A in English, B.S.M.E., and M.A in Education from Tufts University. Her research interests utilizing the create support resources for educators implementing engineering education. She is currently a PhD candidate in Tufts' Math, Science, Technology and Engineering Education program.

Appendix A: Survey and Interview Documents

ASEE Paper Interview Protocol

1. Please Tell us your name, major, and year.

2. What program are you involved with?

3. What classroom or setting do you or have you worked in?

4. What do you find interesting or engaging about your field of engineering?

5. Was there any person or experience that impacted your decision to become an engineer?

6. How did you get started doing outreach?
   a. (if chose outreach) Why did you choose to be involved with outreach?

7. What interested you about outreach?

8. Do you participate or do you plan to participate in research?
   a. (If they do research and outreach) – How do you balance research and outreach?
   b. (If they plan to do research) – Do you think you will you continue to do outreach when you do research or will you need to stop doing outreach?

9. What do you find interesting or rewarding about outreach?

10. What do you find difficult about outreach?

11. Does or has outreach have/had any impact on your engineering skills or knowledge?

12. Does outreach build any useful skills that aren't part of your engineering courses?

13. What responsibilities do you think engineering have for education?

Name: ____

Date:____

Post Interview Survey

Please rate how outreach has impacted your life in the following ways
-5 (a significant negative impact or your life or skills)
0 (no impact)
5 (a significant positive impact on your life or skills)
Circle one

1. Your leadership skills

-5 -4 -3 -2 -1 0 1 2 3 4 5

2. Your Understanding of engineering concepts or skills

-5 -4 -3 -2 -1 0 1 2 3 4 5

3. Your self confidence

-5 -4 -3 -2 -1 0 1 2 3 4 5

4. Your confidence in your engineering knowledge of concepts or skills

-5 -4 -3 -2 -1 0 1 2 3 4 5

5. Your communication skills

-5 -4 -3 -2 -1 0 1 2 3 4 5

6. Your presentation skills

-5 -4 -3 -2 -1 0 1 2 3 4 5

7. Your time management skills

-5 -4 -3 -2 -1 0 1 2 3 4 5