120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #5758

Model for Undergraduate Outreach Project Involving Community Engagement

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Abstract

The United States needs more engineers in order to meet the demands of our economy and workforce. To spark interest in engineering and engage the community, undergraduate engineering students enrolled in a Strength of Materials course were required to create and implement an outreach activity. The activity was designed to engage the students in an engineering concept while also learning what engineers do and the broad scope of engineering. Working with students one morning at the local middle school with hands on activities, the undergraduates presented concepts of buoyancy, electricity, strength of materials, and mechanics.

The middle school students were asked to fill out a survey designed to gauge their perceptions of engineering before the activities began. In addition, the undergraduates were given an open ended reflection framed as a "What happened?" "So what does it mean?" and "Now what will you do?" prompt.

The responses were coded and tallied. The middle school students showed they have stereotypes about what an engineer does. When asked to draw an engineer, students drew males (77%), tools (63%), and hardhats/caps (32%). Thirty-six percent of the students did not know an engineer; of those that did, 74% were males. A majority of undergraduates (66%) believed that the outreach program was successful in sparking interest in the middle school students. Undergraduates were also enthusiastic about continuing outreach projects after graduation (77%) and were invited back by the middle school teachers for future outreach activities.

This project formed an important link between the college and the community. This relationship will lead to more opportunities for future outreach projects and a more knowledgeable community on engineering. In addition, this outreach project exposed the undergraduates to the demand for more engineers and encourages them to continue outreach in community.

Introduction

The United States is increasingly looking to engineering as part of the solution to our recent economic downturn, as well as to global challenges including sustainability and ever-changing technology. To this end, President Obama set a goal to graduate 10,000 more engineers each year from American institutions [1]. In addition, Energy Secretary Steven Chu has stated, "We need engineers. We need scientists. This is going to be at the heart of how the United States is going to remain competitive" [2]. Before his death, Steve Jobs said to President Obama that he could move production of Apple products to the United States if, and only if, 30,000 engineers can provide on-site support to manage 700,000 factory workers. Also, Jobs suggested that all foreign students receiving their engineering degrees in America be granted

visas to stay and work in the country [3]. Taking a cue from these leaders, current engineers and engineering educators have a responsibility to engage the larger community in encouraging more students to pursue engineering degrees.

One way to encourage more students to consider engineering is through outreach projects. There are a variety of approaches to outreach, but those that involve undergraduate engineering students accomplish two goals: 1) encouraging more K12 students to consider engineering by breaking stereotypes, and 2) involving the undergraduate engineering students in meaningful community engagement, which they will hopefully continue throughout their careers.

There are several reasons that involving undergraduates in outreach is particularly effective, primarily because they can break the stereotypes of engineers that most K12 students have in their minds. Obama administration officials have met with business executives and school deans in order to better understand the barriers to creating more engineers, which were identified as scientists and engineers being depicted as nerdy, geeky, and "uncool" in pop culture, and that K-12 schools are not educating students about what an engineer does and how important they are to everyday life [2]. Undergraduate students can help in this mission because they are young, fun, and hard working. College students visiting high schools and middle schools can show the young students that engineers are "cool" people who wear normal clothes, play sports, and solve the problems of everyday life. In addition, diverse college students can serve as role models to show that there are females and minority engineers.

For the undergraduates, the outreach project provides an opportunity to engage with the local community as a service-learning project that is "a course based, credit-bearing, educational experience in which students (a) participate in an organized service activity that meets identified community needs and (b) reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility" [4]. This type of curricular community engagement has been shown to have many benefits for undergraduates including: enhanced critical thinking and better understanding of course material, cooperative learning and tolerance for diversity, self-efficacy and leadership, recruitment and retention of students, community-college connections and citizenship [5, 6]. These community engagement activities have been found to impact women and minority engineering students particularly positively [7, 8]. For Elizabethtown College students, in particular, the outreach project provided an opportunity to live out the College's motto "Educate for Service."

Methods

In an undergraduate Strengths of Materials class a group outreach project was assigned. The course is taught at an ABET-accredited regional, private liberal arts college that has fewer than 2,000 students. The course had 22 students including 10 sophomores (45%), 11 juniors (50%), and 1 senior (5%), 16 men, and 6 women (27%).

Outreach Project

An outreach project was assigned in the place of two weeks of laboratory in a Strength of Materials course. Students were in groups of 4-5 and were given four weeks to design and

construct an interactive demonstration of an engineering concept, which was then presented one morning at a local Middle School.

The specific aims of the outreach project described in the project statement (Appendix A) were:

1. to excite middle school students about science and engineering and break down misconceptions about engineers, and
2. to instill in undergraduate engineering students the need for science outreach while giving them an opportunity to creatively teach course content.

The learning outcomes were expressed as the following::

- identify a concept related to engineering
- design and construct a demonstration, experiment, or activity to explain the concept
- teach your concept to middle school students
- engage the younger students on their level, using non-technical vocabulary and everyday experiences
- implement Elizabethtowns College's motto **"Educate for Service"**

The outreach was explicitly related to the College's motto, "Educate for Service" and was also explicitly related to the following ABET outcomes in the project statement:

1. ABET a. Ability to apply mathematics, science and engineering principles. (know engineering concepts/theory *well enough to explain to kids,* and apply them to real-world examples)
2. ABET c. Ability to design a system, component, or process to meet desired needs. (design an activity or demonstration to teach a concept *using creativity and innovative ideas*)
3. ABET f. Understanding of professional and ethical responsibility. (need for outreach and science education to the public, professionalism)
4. ABET g. Ability to communicate effectively. (to a non-technical audience, with multimedia presentation and in written report)
5. ABET i. Recognition of the need for and an ability to engage in life-long learning. (reflect on experience and continuing outreach after graduation)

The groups chose an engineering concept from their coursework, and designed and constructed a demonstration or activity to explain that concept. Groups chose a variety of topics ranging from strength of materials, electricity, and fluids. With such a wide array of engineering disciplines, the students were enlightened on a variety of engineering concepts as well as what engineers do in everyday jobs.

On a Monday morning, the 22 undergraduates met at the local Elizabethtown Area Middle School. For the first two periods of the day, a total of four science classes taught by three different teachers rotated amongst the outreach activity stations. There were two stations set up in each of three classrooms, and the 8th grade students in groups of approximately 8-10 spent about 15-20 minutes at each station. Two of the 8th grade teachers were contacted by the Strength of Materials professor through a campus contact with the Science in Motion program, which

operates as part of Elizabethtown College's Center for Community and Civic Engagement. Science in Motion provides a mobile lab with science equipment beyond the budget of most schools along with science teaching support. At that point, the professor and 8th grade teachers arranged the logistics of the visit, and brought the other 8th grade science teacher on board.

This outreach experience was awarded an internal faculty grant of $1000, but the total cost of the experience was only about $200 for materials and copies, with the remainder used for dissemination expenses. The undergraduates provided their own transportation to the school. Many of their demonstration materials came from reusable demonstrations in the department, very inexpensive supplies like wood, borax, light bulbs, and some materials were donated by local shops, such as two broken bikes for a gear demonstration.

Assessment of 8th Grader Perceptions

In order to gauge the 8th grade students' perceptions of engineers and scientists, the students were asked to fill out a 15-minute survey (Appendix B). After the middle school students had completed the survey, they were collected and later coded and scored by the undergraduates as a class.

The survey first included a prompt that asked the students to draw an engineer in the space provided. This exercise was used to gain understanding of the picture in the students' minds when they thought of an engineer, including gender and defining characteristics. This perception was triangulated by asking to describe in words what an engineer does. These two questions were coded at the same time looking for the same themes. We then probed how students formed this perception by asking the middle school students if they know any engineers. A follow up question asked the students if they did know an engineer, who was it (aunt, uncle, mom, dad or a neighbor Bob)? Specific interest was in seeing if the middle school students knew male or female engineers and if they were family. The final question investigated the students' interest in engineering and the sciences, asking the student if they would ever consider being an engineer or scientist, and why or why not. When the responses were coded, themes emerged for money, liking design, and being hands on.

After the undergraduates divided up the surveys, coded the responses, and shared the results, an additional student researcher separately coded all of the responses for consistency and validation. All of these results were tallied and analyzed in Excel. For each question, the data was tallied and percentages were calculated in order to compare the data. The coding of the open-ended responses involved binary coding. If the student indicated a certain characteristic or key word then a one was recorded for that student and that characteristic or key word. This was completed for all of the students and then totaled at the end. In addition to totaling the whole sample, male and female students were separated and analyzed as well.

Assessment of Undergraduate Experiences

Assessment of the undergraduates' response to the outreach project was conducted with an open-ended individual reflection written after the outreach experience. The reflection was framed as a "What Happened?" "So what does it mean?" and "Now what will you do?" prompt inspired by a previous paper on outreach [4].

- What (happened)?
    - Describe "the facts" of what you did and what happened while you did it, including the challenges and successes you had
- So What (does it mean to you)?
    - Discuss your feelings, ideas, and analysis of the experience.
    - Specifically concentrate on your own feelings about participating, what you thought about the impact you made on the young people, and what you thought about the broader implications of the outreach experience pertaining to the diversity of the engineering field and young people's awareness of engineering
- Now What (are you going to do)?
    - How did this activity relate to Elizabethtown's motto "Educate for Service"?
    - Will you continue outreach and life long learning about the engineering field/ diversity after you graduate? If so, how?

All of the responses were coded using custom software to detect and tally themes for the qualitative results. Identifiers were used to maintain anonymity of the respondents, and data was stored on a password-protected computer.

Results

There were a total of 84 middle school students that participated in the survey. Of the students, 34 indicated a male gender, 48 indicated a female gender and 2 indicated no gender at all. Of the undergraduates, all 22 students (16 male and 6 female) participated in the outreach event.

The middle school students showed they have stereotypes about what an engineer does. When asked to draw an engineer, students drew men (77%), tools (63%), and hardhats/caps (32%) (Table 1). 91% of males and 67% of females drew figures with male qualities, such as facial hair, short hair, and caps. Only 6% of males and 29% of females drew figures with female qualities, such as long hair or ponytails. More engineering stereotypes were discovered as almost one-third of the students of both genders drew hard hats or caps, about 15% of both genders drew a car or engine in the picture, and some depicted bridges. These were the only defining characteristics depicted of an engineer.

Table 1: Middle school students' perception of engineers

	Male	**Female**	**Tools**	**Hard Hat/ Cap**	**Car/ Engine**	**Bridge**
Total	64	17	52	27	14	4
% Total	77.1	20.5	62.7	32.1	16.9	4.8
Male	31	2	18	11	5	0
% of Male	91.2	5.9	52.9	32.4	14.7	0
Female	32	14	33	15	9	4
% of Female	66.7	29.2	68.8	31.3	18.8	8.3

Thirty-six percent of the students did not know an engineer; of those that did, 74% were men (Table 2). It is interesting to notice that the students only knew two female engineers out of the 84 students surveyed. Also, of those that knew an engineer, about one-third of those engineers were family members, for both genders.

Table 2: One-third of the middle school students did not know an engineer.

	Does NOT know engineer	Knows engineer	Male	Female	Family
Total	30	53	39	2	30
% Total	36.1	63.9	73.6	3.8	36.1
Male	14	19	14	0	11
% of Male	41.2	55.9	41.2	0	32.4
Female	15	33	25	2	19
% of Female	31.2	68.8	52.1	4.2	39.6

The survey also asked the student why they would, or would not become an engineer or scientist (Table 3). This result was approximately evenly split with about half of the students interested in considering an engineering or science career. Of note, all of the students that said that money is a reason to consider a STEM career were male.

Table 3: Students were evenly split on possibly becoming an engineer or scientist, although more male students were open to a career in engineering or science, and mostly for financial reasons.

	NOT interested in STEM career	Interested in STEM career	For Money	For Design	For Hands On
Total	39	37	5	5.0	6
% Total	47.0	44.6	6.0	6.0	7.2
Male	12	19	5	2	4
% of Male	35.3	55.9	14.7	5.9	11.8
Female	26	17	0	3	1
% of Female	54.2	35.4	0	6.3	2.1

Many of the undergraduates' responses were informed by the meta-analysis of the middle school survey. A majority of undergraduates (66%) believed that the outreach program was successful in sparking interest in the middle school students. More male undergraduates specifically thought they addressed the stereotypes of engineers' clothes (56% of males, 17% of females), nerdy-ness (38% of males, 17% of females), and gender (31% of males, 17% of females).

Undergraduates were also enthusiastic about continuing outreach projects after graduation (77%) and were invited back by the middle school teachers for future outreach activities. Many undergraduates mentioned Elizabethtown College's motto "Educate for Service" and saw a direct link between community engagement and the outreach activity. Several also specifically mentioned ways they could continue community engagement through outreach in the future.

Selected quotes from the undergraduate reflections:

"This is the whole premise of the whole "Educate for Service" motto and the reason we are at a Liberal Arts college. The reason people choose a Liberal Arts college should be to expand their opportunities through learning and experiences not available to students enrolled in [traditional] programs."

"Projects like these, which is outreach to the community, will help enforce the idea that when I become a professional engineer, I will continue to do outreach programs and work with the community. It didn't take a lot of my time, and I personally enjoyed teaching these students about several engineering concepts."

"After I graduate, I would be very open to giving tours and talking to younger generations about engineering. Next year's crew of Strength of Materials students should also participate in the outreach program and hopefully build a good connection between Elizabethtown College and the Elizabethtown Middle School."

"As for how I personally will continue to reach out to the community after I've graduated, I can't say exactly what I'll do, but I know I want to go out into whatever community it is that I'm involved in, and expose people to the field I'm in. I want to help change the way people view science and math, to show them that it isn't impossibly hard."

"I also believe some of the students were genuinely surprised to find out that we were engineers. I walked around while the second period of students was filling out the worksheet Dr. Atwood handed out before they broke into groups for the demonstrations. Most of the pictures had men with hard hats or tools. I believe they thought we were "cooler" than they expected."

"The students did not really seem like they knew much about engineering or engineers. I felt that it was important that we all showed up in normal attire; it allowed them to look at engineers as normal people. After looking at many of the student's drawings of what they thought an engineer looked like, it seemed like they viewed engineers as nerdy people wearing lab coats and/or hardhats. To me, changing their view of engineers may make them more interested in science and engineering."

"The eighth graders perceptions of engineers were mostly the same, with a few exceptions. Most thought of engineers as male who fixed and built cars or bridges. Most of the kids had no idea the broad range of projects engineers can be involved in."

"Having the kids say that they are interested in science after our demonstrations was rewarding. Being the reason some of these middle schoolers will go into a science field is exciting. Making an impact on eighth graders is not an easy task. Middle schoolers are very judgemental and the fact that we could make an impression on them that science is fun and "cool" is promising."

"Another thing that jumped out to me was the drawings that the students drew of what they thought an engineer looked like. I think young kids get this stereotypical image in the head that an engineer is a mad scientist with a white lab coat and tools. I think it was good for them to see us talking, dressing, and acting like everyday people and interacting with them in a setting that they are accustom to. The biggest thing to me was that the students go to hear that most of us were involved in other extracurricular activities along with our schoolwork. It was nice to be able to tell them that all four of our group members were involved in athletics at Elizabethtown College."

Conclusions

This model outreach project involving undergraduate engineering students accomplishes two goals: 1) encouraging more K12 students to consider engineering by breaking stereotypes, and 2) involving the undergraduate engineering students in meaningful community engagement. The outreach was performed as part of a course-based educational experience that met local and national community needs and required the undergraduates to reflect on the activity with respect to ABET outcomes of course content, communication, and understanding of engineering as a discipline, as well as their professional and civic responsibility as an engineer. One key aspect to the project was surveying the middle school students and involving the undergraduates in a meta-analysis of the responses, which informed the undergraduate's own reflections of the experience.

This project formed an important link between the engineering department at Elizabethtown College and the surrounding community. This relationship will lead to more opportunities for future outreach projects and a community more knowledgeable about engineering. In addition, this outreach project exposed the undergraduates to the concept of community engagement and encouraged them to think of ways to continue outreach in community.

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Appendix A: Outreach Project Statement

EGR 264: Strength of Materials
Engineering Outreach Project

Project objectives:

The specific aims of this project are two-fold:

3. to excite middle school students about science and engineering and break down misconceptions about engineers, and
4. to instill in undergraduate engineering students the need for science outreach while giving them an opportunity to creatively teach course content.

As a culminating lab project, groups of 3-4 students
• identify a concept related to engineering
• design and construct a demonstration, experiment, or activity to explain the concept
• teach your concept to middle school students
• engage the younger students on their level, using non-technical vocabulary and everyday experiences
• implement Elizabethtown College's motto **"Educate**

for Service" Project Deliverables:

- Engineering concept activity and multimedia (33%)
- Attendance at Elizabethtown Area Junior High on Monday, April 23rd
- A two page typed lab report (double column format) with the subheadings: (33%)
  - Project overview
  - Need for engineering outreach
    - Need for engineers in today's society and our future challenges
    - Statistics on profile of engineers (gender, race)
    - Literature on challenges and solutions to diversify engineering
  - Concept
    - Overview
    - Basic theory
    - Relation to "real-world" (ie, why would kids care?)
  - Outreach Activity
    - Describe and justify your design decisions for your activity/demonstration (photos are a plus!)
    - Describe and justify your design decisions for your multimedia presentation (with references)
  - Lessons learned
    - How would you suggest this particular outreach experience be implemented differently? (did you have enough time? Budget? More/fewer students? Different grade level? Next time make engineering board games, songs? Etc)
  - Appendix: images, more detailed theory, budget, photos of students doing your activity
- Attendance at Scholarship and Creative Arts Day with your activity

- In addition, **individual reflections** must be attached. (33%)
  - At least one page on each heading (typed, 11 point, double-spaced)
  - Headings:
    - What (happened)?
      - Describe "the facts" of what you did and what happened while you did it, including the challenges and successes you had
    - So What (does it mean to you)?
      - Discuss your feelings, ideas, and analysis of the experience.
      - Specifically concentrate on your own feelings about participating, what you thought about the impact you made on the young people, and what you thought about the broader implications of the outreach experience pertaining to the diversity of the engineering field and young people's awareness of engineering
    - Now What (are you going to do)?
      - How did this activity relate to Elizabethtown's motto "Educate for Service"?
      - How will you continue outreach and life long learning about the engineering field/ diversity after you graduate?

Student Learning Outcomes: *Upon Completion of this project, each student should be able to:*

ABET a. Ability to apply mathematics, science and engineering principles.

1 (know engineering concepts/theory *well enough to explain to kids,* and apply them to real-world examples)

ABET c. Ability to design a system, component, or process to meet desired needs.

2 (design an activity or demonstration to teach a concept *using creativity and innovative ideas*)

ABET f. Understanding of professional and ethical responsibility.

3 (need for outreach and science education to the public, professionalism)

ABET g. Ability to communicate effectively.

4 (to a non-technical audience, with multimedia presentation and in written report)

ABET i. Recognition of the need for and an ability to engage in life-long learning.

5 (reflect on experience and continuing outreach after graduation)

Appendix B: Survey for Middle School Students

Grade _____ Gender M F

Ethnicity Caucasian ___ Hispanic ___

Asian ___ African American _

Other ___

Please draw an engineer in the space below:

Describe what an engineer does:

Do you know any engineers? If so, who? (mom, dad, aunt, neighbor Bob, etc)

Would you consider being an engineer or scientist? Why or why not?