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Reflections of College Students Promoting Engineering through Biomechanical Outreach Activities Indicate Dual Benefits

Kimberly Edginton Bigelow
University of Dayton, kbigelow1@udayton.edu

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Abstract

Recent work by the National Academy of Engineering revealed that the public has a poor understanding of what engineers actually do on a day-to-day basis.[1] This issue is compounded for non-traditional fields in engineering, such as biomechanical engineering. This is particularly problematic as such fields could draw interest from students not interested in traditional engineering careers, resulting in increased diversity.

To address this, mechanical engineering students taking an elective course, *Biomechanical Engineering*, were given an outreach assignment to teach at least one individual under the age of 18 about the field of biomechanical engineering through a hands-on activity. Students worked with diverse groups and ages of young adults, with many presenting to classrooms or sports teams. Students were given examples of activities that could be used, including designing functional prosthetic hands out of simple materials.

Upon completion of the outreach, a *What? So What? Now What?* reflection paper was used to assess the impact of the experience on both the student and on the young adults. The reflection was guided by a series of questions provided by the instructor, with students asked to focus on the issue of whether there is a general lack of awareness of engineering careers, especially of non-traditional types of engineering such as biomechanical engineering.

Comments made in the reflections were categorized by the instructor, revealing several common themes. The reflections indicated that both young adults and college students benefited from the activity. College students conveyed their purposeful attempts to tie engineering to the interests of the young adults, while ensuring the appropriateness to the audience. In particular, many noted the challenge of communicating technical information to a non-technical audience. Over one-third of the class reported that the experience helped them realize their own interests and abilities to teach.

College students also reported being surprised with the intelligence, creativity, confidence, and teamwork ability that the young adults demonstrated. Some felt young adults possessed engineering skills, but did not know them as "engineering". Students were also surprised by the interest young adults had for participating, especially as most expected that the field was not viewed as "cool" or "glamorous". Overall, the students felt that young adults didn't really know what engineers did, and were especially surprised that it could be applied to medicine or sports. They felt there was a need to address this, especially with young females, but expressed varied beliefs as to whose job it was and how to best promote engineering.

Introduction

In 2008, the National Academy of Engineering published the report *Changing the Conversation: Messages for Improving Public Understanding of Engineering* to address the concern that many

Americans do not have a good understanding of engineering and engineering-related careers.[1] This lack of understanding was viewed as a particular hindrance with regard to attracting young people to careers in engineering.[1] Ideally with increased understanding of the broad and diverse nature of the engineering field will come increased likelihood of students pursuing degrees to work in engineering-related careers.

One of the detrimental public misconceptions about engineering has to do with the role of engineers in society. Research has shown that the public perceives engineers to be less engaged in societal and community concerns than scientists – and to be less likely to save lives.[1,2] As such, when asked to rate selected professions based on prestige, results indicate that Americans rank firefighters, doctors, nurses, scientists, teachers, military officers, police officers, priests, and farmers all above engineers.[1,3]

Though it can be argued that all fields of engineering interact with societal needs and that protecting and saving lives is an important part of engineering – healthcare-related engineering careers often perform these duties at a level on par with the prestigiously-ranked doctors and nurses. It is clear that this connection has not been made by many, and it is believed that this is in part because of the stereotypical view of engineering careers that much of the public has. Americans may have some ideas of what mechanical or civil or electrical engineers do – but when it comes to specialized fields such as biomechanical engineering, many individuals have not even heard of such a career.

Biomechanical engineering is the discipline where classical mechanics (such as statics and dynamics) is applied to biological or medical sciences.[4] The field is broad, but most commonly focuses on the evaluation of human movement within the context of improving performance and treating and preventing injuries for clinical, sports, and occupational purposes. Engineers working in the field of clinical biomechanics often work closely with physicians, orthopaedic surgeons, physical therapists, and other health professionals evaluating patients' gait, balance, and muscle activity. This quantitative evaluation, enabled by the engineer's use of measurement sensors and data analysis tools, allows for disease diagnosis, monitoring of functional changes, and evaluation of a treatment's effectiveness in a way that traditional observational assessment does not. As such, a biomechanical engineer might even suggest to a surgeon which muscles to operate on in a child with cerebral palsy to help her become more mobile.

Increasing knowledge of such fields may be a significant step in changing the public's opinions of the type of work that engineers do. With this done, it may be easier for individuals to see the clear relationship between engineers and the characteristics so desirable of prestigious careers: working to better society and working to improve lives. It is likely that once this occurs, more young people might consider pursuing careers in engineering. In particular, it is thought such careers might especially appeal to females and others who have not been well-represented in traditional engineering fields. A report by the Extraordinary Women Engineers Project found that "High school girls believe engineering is for people who love both math and science. They do not have an understanding of what engineering is. They do not show an interest in the field, nor…think it is 'for them.'"[5] The same report suggests that this may have to do with the disconnect between career motivators for girls and the messages that girls hear about engineering. One of the most important motivators that help girls determine what field to go into is the ability to make a difference, yet their understanding of engineering comes from the messages they hear that engineering is challenging, difficult but rewarding, and uses math and science to solve problems.[5] If this perception can be changed through exposure to the engineering fields that best exemplify this ability to make a difference and impact lives, females may be more likely to go into engineering.

This paper discusses a service-learning outreach assignment where students taking an elective Biomechanical Engineering class worked with younger individuals to teach them about the field of biomechanical engineering through hands-on activities. The hope of this project was that young people would become knowledgeable, and thus interested, in the field, while the college students would recognize the importance of engineering outreach. The outcomes of this were assessed through a detailed reflection paper.

Service-Learning Outreach Assignment

In Spring 2009, a new elective course entitled Biomechanical Engineering was offered to upperclassmen and graduate students within mechanical engineering at the University of Dayton. Prior to this course offering, biomechanical engineering had not been represented within the School of Engineering. A total of 15 students took the course, 13 seniors and 2 graduate students. There were a total of three female students in the class, all undergraduates. Baseline measurements of biomechanical knowledge were taken during the first class by administering a questionnaire with six open-ended questions such as: *What are some examples of biomechanical problems that can be solved using basic engineering principles* and *What are some common tools that would be used to carry out a biomechanical engineering analysis?* The results of this survey indicated an overall lack of prior knowledge, and many students voiced that they did not really understand what biomechanical engineering was. Many students initially incorrectly assumed that biomechanical engineering covered the same topics as the much broader and diverse field of biomedical engineering. Throughout the course, students learned and became interested in the field themselves, with several suddenly planning to go on to graduate school to specialize in biomechanical engineering.

At the start of the semester, students were given the service learning outreach assignment. The assignment first laid out the problem: “There is a general lack of awareness of engineering careers, especially those non-traditional types of engineering – such as biomechanical engineering.” The service-learning assignment to address this problem required each student to participate in engineering outreach by teaching someone else, under the age of 18, about the field of biomechanical engineering through at least one hands-on activity.

The requirements of this outreach interaction were flexible, giving the students freedom to conduct the outreach in a way that they felt most comfortable. Students were given a checklist of selection criteria, each associated with a number of points based on the required level of effort. Students could pick whichever selection criteria they wanted as long as it added up to the required number of 12 points. This enabled, for example, a team of two to do a 30 minute activity with a large elementary school classroom – or one student to do an hour long activity with a younger sibling. The selection criteria are presented in Table 1. Students were required to choose one selection from each category.

Table 1. Service-Learning Activity Selection Criteria

Category	Selection Criteria and Points
Setting Up Activity Logistics (Contacting group to present to, setting date, etc.)	+3 Done independently +2 Done by one person (could be yourself) on behalf of the team +1 Set-up by the professor (you must come to my office and be present while this is arranged)
Who You Will be Presenting To	+4 A classroom +3 A Girl Scout or Boy Scout Troop +2 A small group of people (at least 2) +1 An individual
You'll be presenting…	+2 Independently +1 With at least one other class member
Number of Activities Presented	+3 At least three activities +2 Two activities +1 One activity
Type of Activity	+2 For each activity you found/developed on your own +1 For each activity available to you that you modified/used your own supplies
Time Commitment	+3 Over an hour and a half doing outreach +2 At least an hour doing outreach +1 At least 30 minutes doing outreach *All can include any extra education
Extra Education	+2 You talked about engineering and biomechanical engineering/showed video clips for at least 15 minutes before starting hands-on activities +1 You talked about engineering and/or biomechanical engineering for at least 5 minutes before starting hands-on activities

In class students learned about several possible hand-on outreach activities. A simple prosthetic hand design competition was completed in class to demonstrate one of the possible activities. This activity, detailed in the following section, was most prevalently included in the completion of the service-learning assignment.

Along with completing the outreach, students were required to submit a written reflection paper following the commonly used reflection format, *What (Happened)?, So What (Does it Mean to You)?, Now What (Are You Going to Do)?*. The assignment explained that service-learning activities offer the opportunity to not only do service that benefits others, but often provide the personal benefits of learning about one's self and their community. Students were provided with prompts to help them reflect on the experience. For the *What (Happened)?* section, students were asked to describe "the facts" of what they did and what happened while they did it. For the So *What (Does it Mean to You)?* section, students were asked to discuss their feelings, ideas, and analysis of the experience. They were to specifically concentrate on their own feelings about participating, what they thought about the impact they made on the young people, and what they thought about the broader picture pertaining to awareness of engineering. For the final Now *What (Are You Going to Do)?* section, students were asked to discuss the broader implications of the service experience and apply it to learning, discussing specifically the problem of the lack of engineering awareness. Specific related questions followed each prompt and explanation. Students were asked to write at least one page (typed, double spaced) for each section. The majority of students turned in papers that were 4 – 6 pages in length.

The completion of the service-learning assignment (outreach and written reflection components) was originally scheduled to be due in mid-March, giving students over two months to complete the project. Based on student feedback, the due date was changed to follow Spring Break to allow for students to perform the outreach in their hometowns, utilizing previously established connections. As such, the assignment was due in the final weeks of class. By doing so, all students were able to set-up the logistics of their activities independently; many saying this was only possible due to the extension.

Details of Prosthetic Hand Outreach Activity

Almost all students completing the service-learning activity included some variation of the hands-on activity requiring the design of simple prosthetic hands made of every-day materials. This activity mimics the engineering design process, and is easy to adapt to different ages and skill sets. It is easy to conduct as an outreach activity because it requires only common household materials, and yet surprises participants by what their designed prosthetic hands are able to accomplish. Though the origins of this activity are unknown, the author of this work was first introduced to the activity, then facilitated by Dr. Robert Hubbard and Dr. Tamara Reid Bush, when she attended the High School Engineering Institute at Michigan State University. The author has since modified the activity to what is described in this section. Students conducting the outreach activity for this service-learning assignment made further modification to meet their own needs and interests.

The goal of this outreach activity is to design two artificial hands that allow several everyday tasks to be accomplished. Though these tasks can be anything, the students in the Biomechanical Engineering course designed for a child who had lost both hands so that she could do typical tasks of an elementary school student. As such the hands had to: 1) Open a sealed Rubbermaid container (to eat her lunch), 2) Open her textbook to the first page of Chapter 7 (to do her school reading assignment), 3) Toss a ball to her friend (at recess), and 4) Zip up her jacket (to head home in the cold).

For the in-class example, the Biomechanical Engineering students were broken up into teams of four. Each team was given two large Styrofoam cups. These served as the base of the artificial hands. Each cup was to be placed over the student's own hands, to be used as the prosthetic. The groups then had a supply of building materials to build the hands, which they taped and glued to the cups to make functional attachments. These building materials included: tongue depressors, rubber bands, plastic cutlery (forks, spoons, and knives), large and small paper clips, and masking tape. Scissors were also provided.

Students were stepped through the design process for this activity. The problem was first defined, and then students had to brainstorm and sketch possible design solutions. Students could then obtain materials and begin building. Students were free to do informal testing and re-design throughout the design process. Finally, at completion of the allotted time (approximately 45 minutes), a final competition was held to evaluate how well the designs allowed the necessary tasks to be completed.

For the competition, one student from each team was chosen for each task. That person wore both hands and completed the task, while being timed with a stopwatch. The times for the four tasks were added to compare the overall design effectiveness for each group. Discussion then focused on task-specific designs, as well as possible future revisions and design changes.

Figure 1 shows a representative set of prosthetic hands performing the task of zipping up a jacket. These hands were made by a team of children who participated in the outreach.

Figure 1. Representative Prosthetic Hands Performing the Task of Zipping up a Jacket

Results of the Experience Based on Student Reflections

The reflection papers indicated that, as expected due to the built-in flexibility of this assignment, students carried out this outreach in a variety of ways. Several students conducted the outreach activities in elementary school classrooms, others taught middle-school sports teams, and some taught a couple of younger relatives. Most of the students performed their outreach activities for individuals in middle school or younger. All included some aspect of engineering education prior to conducting the activity, and most specifically explained what biomechanical engineering is. Several students showed video clips to illustrate their points. In particular a PBS/Think TV video clip available on the internet, featuring the instructor of the Biomechanical Engineering class talking about biomechanical engineering, was used.[6] One student in the course did not perform the assignment as required, conducting outreach for college students, instead of individuals under the age of 18. As such, that student's reflection is not presented in these results. Table 2 shows the breakdown of how the remaining 14 college students chose to structure their outreach assignment. As six of the fourteen students (43%) presented with a partner, eleven unique outreach experiences were conducted and

Table 2. Breakdown of how College Students Structured their Outreach Assignment

Component	Options	Percentage of Experiences
Who You Will be Presenting To	A Classroom	18%
	A Sports Team	27%
	A Small Group of Relatives or Family Friends	55%
	An individual	0%
Age you presented to	Mostly Grades K – 5	36%
	Mostly Grades 6 -8	46%
	Mostly Grades 9 - 12	18%
Type of Activity	Prosthetics Hands Only	64%
	Prosthetics Hands + At Least One Additional Activity	36%
	Activity Other than Prosthetic Hands	0%
Extra Education	Showed PBS/Think TV video	36%
	Showed videos, but not PBS/ThinkTV	27%
	Included Extra Education without video	36%
	Did not include Extra Education	0%

The reflections consistently identified that the experience had been beneficial not only for the young people doing the hands-on activities, but also for the college students facilitating them. After reading through the reflection papers, approximately a dozen common themes stood out to the instructor. Each paper was then re-read to categorize the comments made throughout the reflection into these themes. This allowed the instructor to determine the prevalence of the various thoughts. In addition to these themes, almost all students concluded their reflection with a discussion about how to best promote engineering and whose job it was. These twelve themes and percentage of students who included the theme in their reflection paper are included in Table 3, and further described below.

Table 3. Twelve Common Themes Identified in the College Student Reflections

Related Issue	Identified Theme	Percentage of Students Including
Setting Up and Conducting the Activity	Struggle ensuring information and vocabulary was appropriate for audience	64%
	Effort to tie engineering to young adults' interests	57%
	Recognition of the importance of hands-on/active learning	29%
Lessons Learned about Working with Young Adults	Surprise at younger students' intelligence, creativity, teamwork skills, and confidence	64%
	Recognition of an interest/ability to teach	36%
	Surprise at students attention, enthusiasm, and interest – thought they would be bored	29%
Engineering Awareness	Barrier is to increased career interest in engineering is its lack of glamour/coolness	57%
	Found young adults didn't really know what engineering was	50%
	Emphasized role of teachers in high school to introduce engineering	29%
	Found young adults didn't know engineering could be applied to sports and medicine	21%
	Felt one problem is that students might have the knowledge or background, but can't put the name "engineering" to it	14%
Diversity	Focuses on the importance of girls considering engineering rather than boys	29%

The reflections revealed three common themes regarding setting up and conducting the activity. Most prevalent were comments about the struggle the college students had balancing technical information and vocabulary with enough basic information for a non-technical audience to understand. Related, students also commented on the appropriateness of the material presented to the interests and skill-level of the audience. Over 60% of the class included some comment relating to this. The second most prevalent theme regarding setting up the activity was describing the purposeful efforts the college students made to tie engineering into the young adults' interests. Over half of the class detailed some way in which they tried to do so and/or why they felt it was important to do so. Finally, four individuals (29% of the class) included discussion that indicated they recognized the importance of active learning – either by describing efforts that emphasized good teaching skills or by reflecting on the importance of including hands-on activities in the learning process.

The reflections also revealed several themes regarding what the college students learned about working with young adults. The majority of the class, 9 of the 14 students, wrote that they were surprised at the younger students' intelligence and creativity in terms of design, as well as their teamwork skills and confidence. Several others expressed being surprised by the young people's attention, enthusiasm, and interest in the activity – having originally believed that children would be disinterested and bored to have to participate in engineering tasks. Several of the college students also wrote in their reflections that the opportunity to work with young people helped them recognize their own interest and ability to teach, with some reflection as to how they might incorporate this into their future career plans.

When reflecting on the larger issue of engineering awareness in a young population, the college students generally expressed that there is a lack of understanding and appreciation of the profession. Eight of the fourteen college students expressed that they felt a barrier to increasing interest in engineering careers is the perceived image of engineers, which is lacking of glamour and coolness. In particular, the college students noted the role television and movies have in helping to form these perceptions. Related, half of the college students reported that they found that the young people did not really know what engineering was. Several students also elaborated that the young adults didn't know engineering could be applied to sports and medicine. Others felt that part of the problem is that the young students might have knowledge of or background in engineering, but weren't able to put the name "engineering" to it. Several college students emphasized the role teachers in high school play in (potentially) introducing engineering to students, though noted that the approach some teachers take may actually serve to discourage young people from pursuing STEM careers.

About a quarter of the class did reflect on the importance of girls considering careers in engineering, though interestingly only one of the female students in the class made this comment. Several students did present to all female groups, though it is unclear if this was purposeful to address the gender disparity or whether it was convenient because their sisters were members of the groups.

Though the college students generally agreed that a lack of engineering awareness existed in young people and that efforts should be made to improve awareness, they tended to disagree on how to make this happen. In their reflections, college students wrote a variety of comments on whose job it is to promote engineering and how to best accomplish this task. Though there was no consensus among the reflections, five main potential means were suggested: Teachers, Extra Curricular Activities, University Students, Practicing Engineers, and Television. Interestingly, parents, community leaders, magazines and websites were left off their lists.

Discussion

From an instructor's perspective, this assignment was very significant in changing perspectives of not only the young students who participated in the hands-on activities, but even more importantly the college students who facilitated the outreach. Furlan has described a similar mutual benefit when young college students participated in nanoscience-related outreach activities, though this description was not based on a reflection-based outcome measures.[7] The themes that were identified in the reflections for this assignment revealed this significance, but even more impressively was the change in attitudes of the class about this assignment after they had completed the outreach. Many of the students initially expressed disinterest and anxiety in having to complete this type of assignment. However, in their reflections, class discussions, and course evaluations, they consistently reported having enjoyed the assignment and recommended future classes should also be required to conduct educational outreach. One student even expressed in his reflection that he originally thought the project was going to be "irritating and difficult" – and yet reported upon completing the assignment that it was very rewarding. One of the keys to helping make this project a success was the extension of the deadline for the assignment such that students had access to hometown connections over spring break.

Though this assignment was beneficial in a number of ways, one of the most important accomplishments was the practice the college students experienced in communicating with diverse audiences. The challenge of determining how to best balance the technical information that was important to convey with more easily understood conceptual basics, all while using appropriate vocabulary, was something the majority of college students discussed in their reflections. Though engineering instructors commonly emphasize the skill of communicating with the audience in mind throughout the curriculum, this type of immersive experience exemplifies the importance of being able to adapt to a variety of audiences. It is hoped that the college students who participated in this service-learning activity will be able to transfer the skills learned from this experience to their future coursework and career, enabling them to be more successful.

This work was also important because it opened up the college students to the idea of working with young adults. The college students generally expressed being pleasantly surprised at the abilities and intelligence of the young students. They also expressed recognizing their own interest and abilities in teaching or coaching – while also incorporating elements of quality teaching into their facilitation of the outreach activities. One college student described the "great feeling" of having the students learn from him. These are encouraging realizations, as these college students, who will soon form the next engineering generation, have the potential to be role models and leaders that help promote engineering as a career. The reflections allude to the fact that college students may be more receptive to take on this role because of this experience. However, the college students did not all agree that it is the role of college students and/or practicing engineers to take on such tasks.

Future work is needed to quantitatively assess the effect of this, and similar outreach programs, on changing perceptions of engineering as a career for young students and for changing perceptions of the engineer as a role model and educator for the college students. Prospective monitoring to determine the long-term impact of this experience on both young students and college students would be beneficial. Based on past experience, teaching about biomechanical engineering through the prosthetic hands activity has impact on the career choices of at least some students – particularly females who had not previously known that engineering could be related so clearly to the human body and medicine. Data to more objectively demonstrate this, however, are needed.

Conclusions

The inclusion of a service-learning assignment requiring college students to teach young people about biomechanical engineering through hands-on activities impacted all involved. In particular, young people were surprised to learn that engineering could be applied to sports and medicine and college students were surprised to see how intelligent and creative younger people could be. College students benefited personally from the experience, practicing technical skills such as the ability to communicate with a non-technical audience, while also considering their potential role as teachers, coaches, and mentors in the future.

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