Tufts Outreach to Somerville High School’s Engineering Classrooms: A Reflection of Year One
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Abstract – Two graduate students from Tufts University’s Mechanical Engineering Department spent the 2011-2012 academic year working in an engineering classroom at Somerville High School to determine the possibilities for creating a more permanent outreach component to the graduate curriculum. Under the direction of the high school teacher, the students observed the classroom then organized their own projects and lesson plans to implement addressing a diverse topic range. Reflections of the first year of this partnership are varied but point to some key conclusions and possibilities for developing this into a permanent partnership and component of the graduate curriculum.

Keywords: outreach, high school engineering, partnership, reflections

INTRODUCTION
Under the direction of Prof. Douglas Matson, graduate students Gabrielle String and Paul Sander worked with Mike Maloney of Somerville High School (SHS) and his two honors engineering classes of approximately 30 students total. This outreach effort was designed to widen the breadth of the high school students’ exposure to engineering, to introduce a community outreach component into the Tufts Engineering graduate student experience, and to foster a relationship between Tufts Engineering and SHS Engineering.

BACKGROUND AND PROJECT DESCRIPTION
During the Fall 2011 semester, Gabrielle and Paul each joined Mike Maloney’s engineering classes at Somerville High School once a week. They offered support for students learning Pro/Engineer CAD software, bridge building software, and guided students through LEGO robotics and balsa wood bridge projects.

During the Spring 2012 semester, Gabrielle and Paul each developed a project to run in one of the classes. Mike’s wishes, and the goal of this pilot, was to bring to the classroom projects that were outside the realm of what the students had been introduced to in other lessons. Because there are no Massachusetts state curriculum standards for engineering, and this was only the second year the class had been formerly offered, the range of projects was very flexible.

Project Goals
- Enhance the graduate student experience with exposure to classroom teaching
- Expand engineering knowledge of high school students
- Encourage high school students to pursue an engineering career
- Prepare groundwork for teachers/professors to write NSF grants

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• Measure the impact of graduate student learning
• Expose graduate students to project management
• Determine the feasibility of program implementation in the graduate student experience

IMPLEMENTATION

Gabrielle, due to her research interest and background, decided to bring an environmental engineering project to the classroom. Her project consisted of teaching students about water, water uses, and water treatment in the developed world and water supply, quality, and treatment issues in the developing world. In their working groups, students were provided samples of water from the nearby Mystic River and learned how to prepare them on Petrifilm. Students examined the samples after incubation and counted E. coli colonies ranging from 12-28 per sample and fecal coliform forming units too numerous to count.

Students were then asked to research slow-sand filters, a design discussed in a previous lesson, and determine what materials they would need to build their own filters out of 2 L bottles. Each group constructed two filters and tested the filters mechanical functionality with tap water. The filters were allowed to dry out over a weekend, groups selected their best design, and these were put to the test with water from the Mystic River. Students again used Petrifilm and sampled unfiltered and filtered water. After incubation students examined the films, and chose the winning group design based on how well the filters performed at removing bacteria and fecal coliforms.

Paul’s project was created via his interest in manufacturing. He decided to introduce students to laser cutter technology. Students were asked to select a simple black and white image offline, or to create one of their own, which would be etched and cut on the laser cutter at Tufts University. Paul created a series of training videos on the basics of AutoCAD for the students to watch both as homework and to use as a reference during their projects.

Utilizing the CAD lab computers at the high school, the students learned how to draw simple splines and trace their images to prepare a file that could be read by the laser cutter. After a week of learning AutoCAD and preparing their files, the students sent them to Paul for manufacture. Paul set-up the laser cutter, and cut the students’ designs in clear plastic, videotaping parts of the process to share with the students. Upon successful completion of the project, the students got to keep their designs.

REFLECTIONS

Gabrielle String, 1st year RA, MS 2013, Department of Mechanical Engineering, Tufts University:
“Prior to being at Tufts, I spent four years working with disadvantaged school districts in northern New York as an extracurricular activity while at Clarkson University. During that time I learned about the critical role of having properly trained teachers and access to educational materials. Once again, I noticed how these two items were of key importance in our work with Somerville. Working with the students and Mike Maloney, who as a trained engineer built the basics of design principles into his lesson plans, it was evident that they were already prepared to...
think about engineering principles. Our role was to bring our individual experiences and interests into the classroom to create projects for the student normally outside of the scope of materials Mike has access to. Additionally we attempted to get the students excited about engineering by sharing our experiences and that of our friends in the field.

I think we had success connecting with the students and demonstrating that engineers aren’t necessarily stuffy old men as is typically stereotyped. On average I was only 4 years older than the students, and remember what it was like to be a senior choosing a major and possible career path. I think this closeness in age helped me to relate to the students better and gear my project towards the parts that might have been most interesting to them. Of course, there were still areas of my project that could be improved upon in the future. A definite change would be to spread the lessons out over a longer time frame to give the students a chance to become fully comfortable with the material. Although not all students are going to be interested in all projects, strategizing new sub-activities of the water project to engage a wider audience of students would also be a change.

Not only was teaching at Somerville an enriching experience, it was also a chance for me to work on my technical communication skills. Learning how to pare down a project and distill the essential information was an important task and skill learned. Only from there were we able to grow the project and learning experience for the students.”

Paul Sander, 2nd year RA, MS 2012, Department of Mechanical Engineering, Tufts University:

“I was really excited to have an opportunity to share my joy for engineering with high school students and was amazed that engineering was offered as a high school course. It was awesome to have complete flexibility with the teacher, Mike Maloney, and his students. As a high school student, I built water rockets as a hobby and thought that I could share my enthusiasm for this fun engineering project with current high school students.

Originally I wanted to design a multifaceted water rocket project involving design, manufacturing, some basic data analysis, and include a competition. Yet as I was finishing up my master’s degree, it became clear that it would be difficult to plan and achieve such an involved project. Instead, I scaled the project back to a laser cutting design project that essentially had just a single requirement: a 2D design in AutoCAD.

I knew the students were capable of using CAD software since Mike Maloney had taught them the basics of Pro/Engineer. It was a fairly easy transition into the CAD lab for most students, and after making some instructional videos available to the students on tablets, most students quickly learned new commands and features in AutoCAD while I assisted those students who needed extra help.

Overall the project went very well. Having more time in my schedule and a few private classes in the CAD lab for simultaneously introducing all the students to AutoCAD would have improved the project. I realize there is a wide range of natural ability and interest in design software packages, as well as in learning new software. I think all of the students learned the software in a unique way, and I was grateful for the opportunity to personally help each of them as they completed their designs. I wanted to emphasize that CAD is an important engineering skill and that it doesn’t take much beyond knowing CAD to produce a simple product with certain types of specialized manufacturing equipment.”

Mike Maloney, Physics and Engineering Teacher, Somerville High School:

“Overall the experience with the Tufts engineering department and students Gabrielle and Paul was extremely positive. Our engineering class was originally designed as an experience for possible future engineers by trying to give them a taste of introductory engineering topics. We wanted to provide students with as broad a range of subjects as we could, but this is tough in a high school setting due to facilities and resources. The Tufts students did a wonderful job of introducing the high school students to the current state of engineering and then working through projects that allowed them to see how engineering is done in the real world.

I had done some CAD training with the students already, but allowing them to actually create a prototype part using the laser cutter really showed them what happens after the design is done, and is something that I could not have
recreated without the help of Tufts. As I have training in Mechanical Engineering and Physics, areas like Environmental Engineering are where the class is lacking. The Environmental Engineering project where students tested samples, then created their own filter systems and analyzed how well their designs worked allowed me to add a unit that I did not really have the capability to do before the collaboration with Tufts.

Both of these projects allowed the high school students to see a different side of engineering and also complete some projects that expanded our curriculum. It was a great experience for both me and my students, and I look forward to continuing it in the future.”

Douglas Matson, Associate Professor and Faculty Advisor, Department of Mechanical Engineering, Tufts University:

“For me, this project was to accomplish two tasks. First, it gives my grad students real-world mentorship responsibilities in a classroom environment. We are training the future leaders and educators and in engineering we often accentuate only laboratory and scientific communication skills. The people component is often missing. Second, it allows me to give back to the community while forcing me to see how my research can be brought to a level where it becomes important to non-academics. I often find it hard to distill what I do to in casual conversation. How can I engage a younger audience and make fundamental research accessible to everyone? Thus my goal in initiating this collaboration was to learn if this type of outreach is sustainable. Can cutting edge research be done in parallel with education outreach given the time constraints on our students? If so, the expectations for our grad students can be expanded to enrich both their education and the curriculum of local schools.

Looking back over the past year, I feel we had mixed results. Both students were totally committed and the high school students and teacher welcomed them enthusiastically. But time constraints are tight and the level of self-inflicted stress needs to be scaled down. Timing in the graduate experience seems to be a key control parameter. Doing outreach in the first year of grad school is manageable given much of the expectation is on finishing a structured series of classroom experiences designed to increase the students personal skill-set. To a student, outreach is just another structured activity – albeit one that is exceedingly fun. In the second year, unstructured research activities become more important and outreach is in competition for valuable thesis preparation time. Discomfort comes when students feel torn between the need to graduate and the desire to fulfill a perceived responsibility to a group they have come to value as junior colleagues – the mentor does not want to disappoint the mentee. In future years, I believe second-year graduate students should “graduate” from their instruction responsibilities to serve as consultants who tutor first-year class volunteers. Both gain the benefit of “seeing the job to completion” and thus both see a path to ensuring sustainability of the outreach activities.”

DISCUSSION

Learning Outcomes

Upon entering the classroom last fall, the students were not totally sure of what to expect from this outreach experience and spent most of their first semester learning from Mike. It became evident via the observation sessions that the classroom ran at a much slower pace than was anticipated and the interactions between Mike and his students more casual than expected. An important lesson they learned from Mike about project structure was the need to create deadlines and “mini-tasks” for the students to accomplish. He had found that students were more able to tackle large projects if they were guided by intermediate goals and suggested that Gabrielle and Paul adapt this model. This model also helped projects flow along and prevented students from getting too backlogged in their work.

Because the engineering class is largely a series of projects in lab groups, there is not much traditional classroom structure. The graduate students learned from Mike how to maintain a laid-back classroom atmosphere while still ensuring progression was being made on projects. A typical class period started with a five-minute overview of the day’s work and expectations followed by Mike circulating through the groups to check in on work and group needs. From this, both Gabrielle and Paul learned how to better formulate and conduct a project with students, and how to communicate both tasks and design information more clearly than when they started.
Paul found that it required a lot more planning and time to complete his project than initially anticipated and found he had to scale back his original ideas from the bottle rockets to the laser cutter project. The original bottle rocket project was subdivided into intermediate projects for the students: learn basic principles of rocketry, design nose cone and fins in CAD software, learn how to 3D print nose cone, learn how to cut fins on the laser cutter, rocket construction, and rocket launching. Mike identified the difficulty in accomplishing so many tasks in a little more than a month and asked Paul to reorganize some of the intermediate steps. The second version of the project was similar, but did not involve the CAD design and manufacturing. After further adjusting, Mike asked Paul what part of the project he was passionate about and what he would like to expose the students to. Paul answered manufacturing, and decided to bring back the idea of CAD design and implementation. Thus, he had distilled his original idea into a feasible project to be carried out with the students.

Paul also found that it was more difficult to complete this pilot program as a second year graduate student while also finishing his thesis work. Gabrielle learned a lot about how to manage a classroom and keep students on task within working groups. She also found that after getting to know the students better she was able to tailor activities and discussions to their interests and find ways to help them connect to the lessons.

**Future Work**

This year’s work was the groundwork for a yearlong pilot program that will be implemented in the 2012-2013 academic year. Gabrielle is working on developing assessments to determine the impact graduate students have on the high school students understanding of STEM. We hope to encourage more students to think about the STEM field, learn how to critically problem solve, and maybe even choose STEM careers via college or technical training. Longer assessments will allow us to determine if it will be possible for Tufts Engineering graduate students to complete such an outreach and have an even richer post-secondary experience.

**CONCLUSIONS**

Wide-ranging conclusions can be inferred from the outcomes of the SHS-Tufts partnership this year. One thing that is most clear is that if this is to become a more formalized and lasting partnership, some sort of structure needs to be put in place to guide the program. These structures would come from a more defined set of goals for the program to ensure that benefits are being gained by both parties. The second year of the pilot program should entail defined objectives and assessment measures. From there the structures could be refined and retailed as the needs of both the high school and university become more clear in this venture.

There are, however, some more immediate conclusions that can be drawn from this first endeavor. A critical one is the timing of the outreach in the graduate student curriculum. As Paul demonstrated, it was much more difficult for him to balance organizing the lessons while in his critical research semesters. For Gabrielle, the work at the high school fit better into the defined class schedule where there were few unexpected issues that arose to consume her time. Creating a system of tiered mentoring for the graduate students is appropriate in addressing these issues.

Another conclusion that Paul and Gabrielle reached after their first semester of observation was that the pace of the classroom was much slower than anticipated. Noticing this was a critical component in organizing their projects in the spring. This is something that will have to be observed with each group of high school students so that projects can be tailored in return. Another conclusion that can be reached more specifically about the projects is that they should be adapted to the specific interests of the class.

A final conclusion of this past year is the need for the graduate students to coordinate with the supervising teacher on some general STEM information lesson plans. For instance, Paul and Gabrielle put together a presentation for the students that consisted of an overview of the different types of engineering, possible career paths, and sample “day in the life of…” pamphlets. The students reacted positively to this sort of info session and expressed a desire that it were more exploratory and been given more time. Incorporating this type of lesson plan into the classroom
would allow the graduate students to get a better sense of the backgrounds and interests of the students and to help open up the dialogue about STEM careers.

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Gabrielle String
Gabrielle is a Masters Candidate in the Department of Mechanical Engineering and a member of the Water: Systems, Science, and Societies Program at Tufts University. As a member of Engineers Without Borders projects in numerous locations she has become focused on technical community education and project evaluation. She has coordinated several high school education partnerships including Science Olympiad coaching in Northern New York with Clarkson University and the current program at Somerville High School. Her research interests include water diplomacy, engineering for underserved populations, and community education and development.

Paul Sander
Paul Sander is a Research Engineer in the School of Engineering at the University of North Florida. He is currently involved in implementing finite element analysis simulations for the advancement of nondestructive pavement testing research. He received a Master of Science in Mechanical Engineering from Tufts University in 2012 with a focus in materials science and heat transfer. His research interests are in heat transfer, fluid dynamics, manufacturing, and materials science.

Mike Maloney
Mike is a Physics Teacher at Somerville High School currently teaching AP Physics, Honors Physics and Honors Engineering. He also is the Science League Team Advisor, Yearbook Advisor and Science representative to the schools Curriculum Committee and School Council. Mike has a Bachelors of Science Degree in Mechanical Engineering from Boston University and a Masters in Science Education from UMASS. Mike has also taught at Northeastern in a NSF sponsored program for teachers earning a masters in education. He is very interested in Physics Education Research and has been involved in the ITOP program and Physics Teachers Network at Boston University and us currently working on developing simulations and online resources for students of Physics.

Douglas Matson
Dr. Matson is an Associate Professor in the Mechanical Engineering Department at Tufts University. He coordinates service learning opportunities for undergraduate students in his role as advisor to the Tufts student chapter of Engineers without Borders and for graduate students as part of a NASA sponsored community outreach efforts in local high school systems including Somerville MA. His research interests are in manufacturing, materials science and selection of appropriate technology for sustainable engineering projects.