

Board 20: Engagement in Practice: First Year Students as "Engineer for a Day" for Middle School Students

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Engagement in Practice: First Year Engineering Students as “Engineer for a Day” for Middle School Students

Abstract

Merrimack College, a small, liberal-arts college, has a long-standing tradition of service learning, and standing relationships with local after-school programs in under-served communities through our Service Learning Center. However, these service experiences have not been integrated into the engineering curriculum. The motivation to integrate engineering majors into this particular service learning project is to demonstrate to engineering students that:

- engineering careers can provide great benefit to local communities,
- although just starting college studies, first-year engineers can mentor youth who may never have met an engineer, and
- communication skills are crucial to practicing engineering.

For the past several years, all first-year students majoring in civil and mechanical engineering, approximately 90 students per year, have been required to participate in these afterschool programs as “Engineer for a Day.” One engineering major from the class accompanies several students from other majors to an after-school program to assist running a STEM activity. The importance of communication in engineering, and of practicing the communication of complex engineering topics to a general audience, is emphasized throughout the course. The engineering students complete a reflection upon return to campus, discuss the experience in class, and use the skills practiced in other projects throughout the semester.

Introduction

There are many challenges in STEM education, including stimulating student interest, retaining students of diverse abilities and backgrounds, and preparing students to address the realities of the post-academic world and work-space. Many novel approaches have been developed to address these challenges, including problem- and project-based learning [1], entrepreneurship [2], and flipped classrooms [3].

First-year engineering students face many unique challenges, including a heavy academic load of primarily technical courses. Engineering student success has been shown to be helped by increasing students’ peer-to-peer instruction [4], and increased efficacy [5] and increasing students’ personal connection/epistemology to their work [6]. Some populations have been shown to have increased retention with increasing awareness of the positive impact engineers can have on communities [7]. Additionally, students may improve their confidence in selection of major by early exposure to engineering practitioners [8], [9]. Although many methods have been tried to improve enrollment and retention, these issues have stood for decades.

Merrimack College has tried a unique way to offer engineering students opportunities to instruct others, increase efficacy and connection to engineering studies, while having a positive impact on a community: engineering students acting as mentors in an existing after school STEM support program. The after-school program is primarily designed and implemented by

Merrimack College's STEM Education majors – college students studying to be STEM teachers at the elementary and middle school level. The engineering students therefore support the STEM Education majors and the local youth.

Through participation in this program, engineering majors practice their technical skills, discover that they HAVE technical skills, and practice their communication skills at the same time - developing higher self-efficacy and seeing the community's need for the skills they already have. Meanwhile, middle school students are mentored by college students, gaining insight into what it will take to be on that path, and being inspired to take up a career in STEM. Finally, STEM Education majors provide support to the Engineering majors, and also gain real-application experience with STEM concepts and education. The Education majors typically bring communication skills and experience with youth, while the Engineering majors typically bring technical skills and experience with hands-on activities.

Background

At Merrimack College, all first semester Civil and Mechanical Engineering students are required to take "GEN1001: Introduction to Engineering." The course includes a lecture (covering measurements, exposure to basic statics/mechanics, technical writing, basic software skills, guest lectures, presentation skills, etc.), and recitation (including a group project to design and build an operational windmill). The College also offers Electrical Engineering; those students take a different introductory course, but share the recitation to build interdisciplinary windmill projects. Enrollment in GEN1001: Introduction to Engineering was 96 students in 2017, and 87 students in 2018. Both years the course was taught as two separate, parallel sections.

In the Fall of 2017 and 2018, first-semester engineering students were required to volunteer one afternoon during the semester with the Lawrence Math & Science Program (LMSP), an after-school program in local middle schools in Lowell and Lawrence, Massachusetts. The engineering students were asked which day of the week and which week of the semester fit their schedule, and were then partnered with a school and an activity. A van transported the engineering volunteers, along with volunteers receiving extra credit in other courses and STEM Education majors managing the program, from our campus to the sites and back. Students were given the curriculum for the day's activity about one week in advance of their volunteer day, so they would have a chance to review the lesson. Activities focused on Engineering skills. Engineering students were given one in-class training session, covering what to expect from middle school aged children, where to find the van, responsibilities for volunteers, and an overview of the activities.

Merrimack College's LMSP has served more than 1,200 at-risk middle school students (5th-8th grade) since its inception in 2002 through a Community for National Service Learn & Serve Grant. The program was designed to benefit college students with experiential/service-learning, leadership skills, and STEM literacy, while benefiting middle school students with academic support in STEM fields, and role models for post-secondary education aspirations [10]. The overall goals of the program are for college student mentors to promote civic engagement, provide for experiential and service learning opportunities, and for the middle school students to enhance STEM literacy, cultural awareness, and leadership skills. More specifically for the engineering college students, we also hope they will practice critical thinking skills, encounter

the uses of an engineering degree in benefiting real communities, and see themselves as technical leaders. Through the LMSP, our college currently partners with eight community-based organizations working in neighboring urban centers, Lawrence and Lowell, Massachusetts.

The school system of Lawrence has had “chronic underperformance,” [11], including a high school drop-out rate of more than 50 percent [12] resulting in a takeover by the State Department of Education. Although some gains have been made in the schools since the takeover [11], the students of Lawrence remain in need of support. The city, population 76,377, is the poorest community in Massachusetts, with a median household income of \$39,627 (in 2017 dollars), which is only 53% of the state’s median household income of \$74,167. Over 22% of families in Lawrence are below the poverty line, with over 27% of families with children under 18 years of age living below the poverty line [13]. Over 38% of the population over 5 years of age speaks English less than “very well”, and only 68% of the population 25-years and over has graduated from High School. Nearly 74% of the population is Hispanic or Latino, and over 39% of the population is foreign born [13].

About 10 miles southwest of Lawrence and of Merrimack College, Lowell, Massachusetts is also ethnically diverse and relatively low income. Total population of Lowell, Massachusetts is 106,519. Median income in Lowell is \$48,581 [13], about 66% of the state’s median income. About 18% of the city’s families live below the poverty line, with 25% of families with children under 18 years of age below the poverty line. About 21% of the population over 5-years of age speaks English less than “very well”; 80% of the population over 25-years old has graduated from high school. About 17% of Lowell’s population is Hispanic or Latino, while 27% of the population is foreign born [13].

Table 1: LMSP Survey Results for 2017 and 2018

	n	Mean	Std Dev
2. How valuable do you think the experience is for the KIDS? In other words, how much do you think THEY got out of the experience? (2=very valuable, 1= they got something out of the experience, 0=neutral, -1= they would have been better off doing something else. -2= they would have been better off doing anything else.)	146	1.12	0.73
3. How valuable do you think the experience is for the students in our engineering class? In other words, how much do you think you & your classmates got of the experience? (2=very valuable, 1= they got something out of the experience, 0=neutral, -1= they would have been better off doing something else. -2= they would have been better off doing anything else.)	146	0.93	0.94

Situated about 4 miles from the urban center of Lawrence and about 15 miles from Lowell, Merrimack College is a small liberal arts college in a suburban setting. In 2016, Merrimack College was named to the US News and World Report lists of Best Regional Colleges North, Best Colleges Engineering Programs, and Best Colleges for Veterans. The college has approximately 3,200 undergraduate students, and 575 graduate students. The 90 academic

programs offered include BS in Civil Engineering, BS in Mechanical Engineering, and an interdisciplinary program in STEM Education program available to students majoring in Education. The campus straddles the boundaries of town of North Andover, Massachusetts, (population 28,352; 89% white; median household income of \$105,661) and Andover, Massachusetts (population 33,201; 98% white; median household income of \$143,292) [13].

Maintaining a long-term relationship between a college and community that continues to be useful for all parties, can be challenging [14]. The Service Learning Center provides continuity from semester to semester and year to year, pairing student volunteers with schools, arranging transportation and any needed school supplies, and coordinating with faculty members and students. The Service Learning Center has been and continues to be crucial to the long-term success of the program.

Results and Analysis

After volunteering, the engineering students filled out a short survey on Blackboard. The survey asked students to tell which site they visited, answer two questions with a Likert response (Table 1), and answer an open-ended question about their experience. These questions asked students to reflect on the experience from the perspective of both the middle school students and from their own perspective as college students.

Question 4 was an open-ended question: “Take 5 minutes (look at the clock on your computer!) to describe the overall experience. In particular, if there is anything that could be improved OR that shouldn't be changed, please let me know. You may want to mention... the activity, activity sheet, scheduling, other college students, etc.”

Question 4 began with an encouragement to check the time, because previous survey results had been quite terse. It was hoped that if students actually noted how long 5-minutes was, they would be more thoughtful in their responses.

In particular, the open-ended responses indicate that college students are thinking critically about how to improve the program, are engaging with the younger kids on engineering topics, and are getting benefits from the experience even when they themselves do not see the benefits. Certainly, a case could be made that the students are exhibiting many of the ABET Criteria a-k, including (d) an ability to function on multidisciplinary teams, (f) an understanding of professional and ethical responsibility, and (i) a recognition of the need for, and ability to engage in life-long learning.

Table 2: Sample Responses to Question 4: General Observations/Experiences. Geographic Identifiers have been removed.

ID	Response from Engineering Student	Note
1	Today I taught kids about the functions of the human hand. We then proceeded to build a model hand from foam, straw, sting, and tape. Using these materials we were able to construct a moveable model hand. The kids as well as myself seemed to have fun building and playing with the finished	Student made suggestions on materials, making improvements to the design.

	<p>product. The only thing I would change would be instead of using tape to hold the straw to the foam, I would use glue of some sort because the straw constantly continued to disconnect from the foam.</p>	
2	<p>The activity I had to do with the kids was create an educational board game. The problem I had was trying to help the kids come up with a game on their own without giving them an answer. If the students were notified before hand about the activity so they had time to think on their own then things would've probably went smoother and the final products would have looked better over all. Aside from that, the overall experience was very enjoyable. Listening to the students talk amongst themselves to come up with a good game that they designed was good to see. Helping them come up with new ideas and seeing their eyes widen when they really like the idea was so satisfying to me.</p>	<p>Student made suggestions to improve lesson, and mentioned their own experience mentoring.</p>
3	<p>My overall experience was quite enjoyable. I normally do not working with children but for this specific assignment, I surprisingly enjoyed the experience. The assignment for my week was the "spaghetti house challenge." In my lesson, the students had to learn how to build a structure with yarn, marshmallow, and spaghetti. It was very helpful having the other college students with me during this assignment because they helped me hand out materials and watch the students build their structures. One of the hardest parts of this assignment was actually controlling the students. They were good overall however, they wanted to eat the marshmallows instead of building with them, so I had to keep a close eye on them. It was surprisingly easy for me to help the students build the structures without physically adding things to the existing structure. I was able to tell them that they needed to add more pieces for stability, support, etc. and help them build more successful structures.</p>	<p>Student reports discussing topics (stability, support) that we covered in lecture.</p>
4	<p>The overall experience was very rewarding to me. I felt like I was helping the younger community become more educated on this topic. It was rewarding because I got to learn something new at the same time as the students. This program is definitely a great idea because it shows these younger kids things they could potentially do when they get older and maybe they will like it at this age and stick with it further on in life. You can literally see these kids glowing with excitement as they get things right. My lesson was making a model of a hand and having the fingers be able to move. Once we completed this activity these kids were so fascinated by what they had created. It made me very happy to see them full of joy.</p>	<p>Student reports a mentoring experience.</p>

5	<p>The activity was a good introduction of how to think and steps needed in order to solve a real world problem. The activity did not provide any benefit to the Engineering students other than a nice experience. Not sure what we could do, but there school needs to do better mentioning it because only four students were there. It was probably a lot cooler that college kids came to visit to help them with an after school activity.</p>	<p>The student evaluates the program (good intro to 'how to think', etc), and thinks through how to improve attendance. Even though s/he did not see a benefit, there is solid evidence of practice in critical thinking and program evaluation.</p>
6	<p>I think it was a valuable experience because it put me outside my comfort zone. I didn't know anyone that as going to be there so I was nervous and didn't know what to expect. I got on the van and there was one other boy that was going to Boys and Girls Club too and he was a regular volunteer so he helped me on where to go. When I got there there was very young kids and we had them read a huge packet on the topic reflexes so it was definitely a little advanced for them but they had fun when we did the experiment with rulers. Overall I think it was valuable.</p>	<p>Student describes being "outside my comfort zone." Several responses were similar to this one, describing the details of the visit.</p>
7	<p>Personally I believe that not a lot should be changed. Everything was organized and set up very well. the only thing I'd have to change anything is to ask the kids how they feel about engineering . I feel as if it's always important to see wher their minds are when it comes to what they want to do later on in life. Other than that everything was fine.</p>	<p>Student makes concrete, thoughtful suggestions on how to improve mentoring of the youth.</p>
8	<p>To be completely honest, I did not do the bridge example with the kids. I got there and the teacher just said to help the kids with homework if they had any questions. I really enjoyed that, I was able to get to know a kid and with the 1 on 1 help he was more successful with his homework than he would have been alone doing it at home . I never really had the opportunity to volunteer in this type of way and for me it was extremely valuable and I had a lot of fun going. The only thing I would say is to make sure the teachers there are aware of the lecture that is supposed to be given and or don't expect an example to be taught. I feel as if young kids don't have the attention span to sit and try to create a bridge without a good incentive, so if I was to do the activity I personally don't believe it would have gone well, or at least with the age group I was with. Overall though, I 100% believe that going to the school is good for first year students in Intro to go I wish I had the opportunity to do it last year. It's super valuable if the kid going there goes in with</p>	<p>Student did not do the assigned project, but still gained a great deal of benefit from the experience.</p>

	excitement and an open mind to do something a little out of the normal, instead of going with the idea its just for a class to just get it over with. Hope this was helpful!	
9	Overall I went in very unsure of what to think. When I got to the school the other student who I was working with explained that he went in blind the week prior and the activity was too difficult for the students to complete; however, we agreed that the lesson plan we were given was going to be fun. Our activity was to create a life jacket for a small army man. We did this by providing the students with sections of a pool noodle, scissors, and rubber bands to fasten the "life jacket" to the figures. The students designed and modified their life jackets multiple times and had an overall good time. I was able to conect with the students and they were excited to meet somebody new. Overall I had fun, though I was a bit stressed at first.	Student describes mentoring the youth through the design process.
10	The activity for me was the spaghetti house, as an engineering student in college, the students thought that it was very interesting how I could give advice on how to build the structure. Also, I am from a small town where I am very priviledged. This experiance mostly made me appreciate that I am in school and can afford college where some other kids do not have these oppurtunites because of financial struggle (no matter how smart these kids are). I think that this was a great experiance and I would definitely take the time to return to this location because all the kids I worked with were great kids.	Student describes the experience of meeting youth from a different demographic group.
11	In my opinion, going to the school in was a waste of time. The kids made a mess, and they did not seem to give any care towards the activity. My class was a mix between 2nd and 6th graders, and the little kids had no care in the world for the activity. In fact, they just ended up throwing the sand and rocks at each other. The older kids understood the activity and did it several times. I think in order to have this activity means something to these kids, they have to be older. If they were middle school or high school kids, they would have gotten something more out of it. This activity may even help them decide where they would want to study this subject further. But those kids have probably already forgotten the activity and the are on to the next thing. It was just a waste of time for me, the kids, the teacher, and the janitor.	Even though student felt the exercise was a complete "waste of time" there is evidence of critical thinking about how to improve the activity.

The NSF Science Education for New Civic Engagement and Responsibilities (SENCER) Student Assessment of Learning Goals (SALG) tool was used to assess overall student outcomes for the

Civil and Mechanical Engineering students. The results for the question “HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?” with a Likert scale of 1 = no help, 2= a little help, 3 = moderate help, 4= much help, and 5 = great help. The results are shown in Table 3. While volunteering with the LMSP has the lowest average, indicating that, on average, the students felt that it was less use to them in helping their learning – it also had the highest standard deviation. Approximately the same number of students found it of moderate help as found it of great help.

It was hoped that perhaps students who struggled with the lecture or the lab would have been the students to get the most out of the LMSP, that volunteering appealed to a different population than other aspects of the course. This did not seem to be the case. Students that said volunteering with the program was “no help” or “little help” (1 or 2 on Likert scale), gave an overall average

of 3.0 (n=37; Standard Deviation: 1.2) to all other aspects listed – much lower than the average for the class. While students that said volunteering was “much help” or “great help” (4 or 5 on

Table 3: Results for “HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?” (n=144)

	Average (5=great help; 1=no help)	Std Dev
Attending lectures	3.74	1.23
Participating in discussions during class	3.74	1.14
Listening to discussions during class	3.91	1.12
Participating in group work during class	4.00	1.12
Participating in group work outside of class	3.88	1.06
Doing hands-on classroom activities	4.05	1.09
Specific Class Activities...		
- Volunteering as ‘engineer for a day’	3.50	1.38
- Other activities were listed in survey	N/A	N/A

Likert scale) to their overall learning, gave an overall average of 4.3 (n=84; Standard Deviation: 0.83) to all other aspects listed. Students that got much out of other aspects of the course were more likely to get a lot out of the program, and vice versa. Students who did not see value in the introductory course were perhaps less likely to say they saw value in individual aspects of that course.

Each semester our students work with approximately 160 middle school students for 2 hours a week for 10 weeks. To evaluate the experience of the middle school youth from their perspective, we conduct pre/post surveys of these youth. In our pre/post surveys over the last 11 years, the middle school students indicated an increased interest and understanding of math and science as well as gained skills for science investigations. The greatest increase seen through our surveys is that now 85% of our middle school students indicate a hope to attend college. These benefits pre-dated the involvement of our engineering students.

More recently we have begun to estimate the impact of curriculum enhancements on our middle school students’ attitudes, motivation and interest in Science and STEM related careers. This research is in partnership with PEAR (Program in Education, Afterschool and Resiliency)

utilizing their Common Instrument (CI) measurement tool. These tools provide information on our program quality and student interest in STEM. The results are not yet available for the years including engineers in the program.

Conclusions

The reflections and other collected data show that the engineering majors benefit from seeing themselves as mentors and as having something to share with the community, as well as getting out of their comfort zone and their own culture-bubble. The students themselves did not all feel that they got a benefit from the experience. Generally, students who were “on board” for the course believed themselves to be receiving greater benefit than those who viewed the entire course negatively.

The middle-school students benefit from meeting near-peers who are willing to give of themselves and their time, receiving an aspirational view of the future, and being exposed to STEM and STEM fields. The data collected from the college students show that the college mentors believe themselves to be providing a benefit to the younger students. Data collected from the younger students is not yet available for the years including engineering students in the program.

Our next steps are to further integrate the service learning program into the Introduction to Engineering curriculum, with more substantial reflection and synthesis, and in having the engineering majors mentoring each other through the experience. We also hope to further solidify the connections of this program to the new ABET criteria 1-7, and to develop metrics that help us make continuous improvement in how students understand their experience.

References

- [1] J.E. Mills and D.F. Treagust, "Engineering education—Is problem-based or project-based learning the answer." *Australasian journal of engineering education*, 3(2), 2003, pp2-16.
- [2] M. Täks, P. Tynjälä, and H. Kukemelk, "Engineering students' conceptions of entrepreneurial learning as part of their education." *European Journal of Engineering Education*, 41(1), 2016, pp53-69.
- [3] J.L. Bishop and M.A. Verleger, *The flipped classroom: A survey of the research*. Paper presented at the ASEE National Conference Proceedings, Atlanta, GA. 2013.
- [4] J. Watkins and E. Mazur, "Retaining students in science, technology, engineering, and mathematics (STEM) majors." *Journal of College Science Teaching*, 42(5), 2013, pp36-41.
- [5] C. Loo and J. Choy, "Sources of self-efficacy influencing academic performance of engineering students." *American Journal of Educational Research*, 1(3), 2013, pp86-92.

- [6] B.A. Danielak, A. Gupta, and A. Elby, "Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention." *Journal of Engineering Education*, 103(1), 2014, pp8-44.
- [7] N.E. Canney and A.R. Bielefeldt, "Gender differences in the social responsibility attitudes of engineering students and how they change over time." *Journal of Women and Minorities in Science and Engineering*, 21(3), 2015.
- [8] P. Sable, S. Karackattu, and M. Traum, M. "First-Year Student Persistence and Retention Influenced by Early Exposure to Engineering Practitioners Co-Teaching Entry-Level Courses: A Four-Year Indirect Assessment," Proceedings of the 121st American Society for Engineering Education (ASEE) Conference and Exposition, Indianapolis, IN. June 15-18, 2014.
- [9] M. Traum and S. Karackattu, "Early Exposure to Engineering Practice Provides Informed Choices for Students Continuing Engineering Programs," ASEE Paper Number AC 2009-432, Proceedings of the 2009 ASEE Annual Conference and Exposition, Austin, TX, June 14 – 17, 2009.
- [10] L.C. Foote and J.E. DiFilippo, STEM Literacy, Civic Responsibility, and Future Vision. *Partnerships for Service-Learning*. Ed. Todd Kelshaw, Freyda Lazarus, and Judy Minier. San Francisco: Jossey-Bass, 2009, pp165-205.
- [11] B. Schueler, J. Goodman, and D. Deming, "Can States Take Over and Turn Around School Districts? Evidence from Lawrence, Massachusetts." *Educational Evaluation and Policy Analysis*. 39 (2), 2017, pp311-332.
- [12] J. Atkinson, J. "Lawrence, MA: City of the Damned." *Boston Magazine*. March 2012. www.bostonmagazine.com
- [13] US_Census_Bureau. *Selected Characteristics of People at Specified Levels of Poverty in the Past 12 Months, American Community Survey, 2013-2017 5-Year Estimates*. 2017. American Factfinder, factfinder.census.gov
- [14] L. Silka, R. Farrant, B. Bond, P. Coffey, R. Toof, D. Toomey, and C. West, "Community-University Partnerships: Achieving continuity in the face of change." *Gateways: International Journal of Community Research and Engagement*, 1, 2008, pp128-149.