AN ENGINEERING WORKSHOP FOR K-12 TEACHERS AND STUDENTS

Michael J. Rust[1] and Abe Kamal[2]
[1]Department of Biomedical Engineering
[2]Department of Industrial Engineering and Engineering Management
Western New England College
mrust@wne.edu

Abstract

This paper describes an engineering workshop developed for K-12 teachers and students. During the workshop, participants compete in a design activity that enables them to role-play as engineers. As a result, the attendees develop basic engineering skills while experiencing first-hand the engineering design process. The results from pre- and post-activity surveys indicate the workshop was successful in impacting student knowledge of the field of engineering. Additionally, the teachers learn simple techniques that can be applied to develop hands-on activities in their own classrooms, thus adding to the long-term sustainability of the outreach effort.

Introduction

There exists a strong desire within the engineering community to conduct outreach activities involving pre-college students. The purpose behind these activities includes increasing student interest and ability in math and science while also introducing engineering as a career option. The primary approach to such activities is to directly engage pre-college students with hands-on engineering activities. Such activities can be conducted in a workshop format by engineers visiting K-12 schools. Alternatively, the K-12 students can attend workshops at local colleges and universities that have engineering programs.

Another route for engineering outreach is to conduct engineering-based activities with K-12 teachers. Such activities give teachers insight into various aspects of engineering, including design and analysis, which can subsequently be transferred to their students during regular classroom instruction. Additionally, since teachers can conduct the workshop activity itself or other similar activities with their own group of students, this approach has the potential to reach a much larger number of students than programs working with students directly. Moreover, such programs are often more sustainable since the teachers can continue to transfer their engineering knowledge to students over the course of several years.

It is important to also give consideration to the perspective of the teacher when discussing such outreach activities. Teachers are continuously seeking new and innovative methods that encourage their students to apply the content they are learning to real-world situations. However, the development of activities that provide such learning opportunities are often perceived as difficult to implement due to the time and cost constraints facing teachers today. In reality, a

wide range of mathematics and science concepts can be explored through the use of simple activities that are fun, low-cost, and easy to implement in a classroom setting. Thus, if teachers have the opportunity to experience such activities themselves, they may be more likely to incorporate similar activities in their own classrooms. As a result, outreach programs that target existing curricular topics with hands-on engineering activities may provide significant value to both educators and students in the K-12 school system.

Background

Outreach programs by colleges and universities that are intended to disseminate engineering knowledge and applications into local K-12 schools are not, in themselves, new concepts. The uniqueness and specificity of the interactive nature of such programs are indeed the requisite catalysts for new visions. As a result, some programs have experienced varied degrees of success, inequity, and sustainability.

Lehigh University, a relatively small, private academic institution, launched an outreach program in 2002 for local middle and high school students[1]. Through this program, undergraduate seniors and graduate students in Materials Science and Engineering disciplines developed practical demonstrations and laboratories in their respective subject matter. The program resulted in a distinct improvement in how high school students viewed the engineering profession, with pre- and post-surveys showing an increased number of students (58% to 97%, respectively) rating engineering as being a "fun job."

Outside of the U.S., academic institutions are promoting engineering-based outreach programs to K-12 students, primarily for the same purpose as U.S. academic institutions. Namely, that engineering provides a viable, fun, and profitable career choice for students. And, to dismiss the prevalent myth that engineering is simply "too difficult" and out-of-reach for the average student. One relevant example is the effort undertaken over the past several years by the Engineering College at the University of Cordoba, Spain. Data obtained by the university have revealed that the number of university students who pursue engineering degrees throughout Spain has dropped dramatically within the last decade. In order to reverse this trend, the University of Cordoba initiated several engineering-related outreach programs with local secondary (high school) students. Some of these programs emphasized the global impact of engineering. As a result of these efforts, the university's first-year enrollment in engineering has stabilized, while it continues to decrease throughout other parts of Spain.[2]

Texas A&M University-Kingsville took a unique approach toward outreach efforts with local high school students to bring about further awareness and recognition of engineering disciplines. They organized summer camps for high school students who have some level of interest in mathematics and science. The camp activities involved basic applied experiments related to different engineering disciplines. The students also learned about existing financial aid opportunities and the various academic programs offered by Texas A&M-Kingsville in the areas of engineering, technology, and science. The survey conducted by the University showed that the camps "increased students' satisfaction, and improved their self-confidence and their interest toward engineering disciplines." The camp was deemed to be an effective and sustainable recruitment and informative tool.[3]

Engineering week has been celebrated in American and international academic institutions to highlight and showcase engineering student achievements to the local community at large. Recently, some academic institutions have developed engineering week activities that attempt to promote engineering as a career choice for young female students, which is a demographic historically underrepresented in the field of engineering.[4] Such programs are intended to attract more young women into engineering through the guidance of their peers, teachers, and parents. Another approach to attracting more young women into the field of engineering is the so called "Y2M" day, or simply, Yes to Mathematics. This program was ultimately intended to bring about further awareness of environmental and civil engineering as a career for young women by emphasizing mathematics fundamentals.[5]

A further approach to outreach programs for high school students is to enable these students to select a particular engineering experience based on their own interests. The Milwaukee School of Engineering is a prime example of an institution developing such activities[6]. The "Focus on the Possibilities" program, undertaken by the aforementioned institution, afforded talented high school students the opportunity to design, build, or test a scale-model race car. This was achieved by the students through the application of solid modeling or solid freeform fabrication (rapid prototyping). Collectively, the students were able to transition from the design concept of the racer to the testing phase of the final unit during the one-week program.

Another unique and successful college outreach program to promote further awareness of engineering disciplines to high school students was undertaken by the University of Ottawa, Canada[7]. The program involves collaborative efforts initiated by both the faculties of Engineering and Education at the university. Engineering course-structured projects were shared and explained to local high school students who had certain interests and aptitude in mathematics and science. Surveys conducted by the university clearly indicate that such an interactive approach is mutually beneficial to both college students and high school students. Specifically, high school students learn how the subjects of mathematics and science relate to real life projects. Simultaneously, it provides a unique dynamic for engineering college students to share the findings of their projects.

Workshop Information

To meet the need for an engineering outreach program in the surrounding community, the School of Engineering at Western New England College developed an engineering workshop that can be used with teachers and students to give both groups exposure to the field of engineering. During the workshop, participants compete in a design activity that enables them to role-play as engineers. Thus, the participants develop basic engineering skills while experiencing first-hand the engineering design process. Additionally, teachers learn simple techniques that can be applied in their own classrooms to develop hands-on activities for their students.

The workshop was developed to support the following objectives:

- Participants will experience engineering work by participating in hands-on, engineering-based activities.
- Participants will learn about the universal aspects of engineering work, including the engineering design cycle and design within constraints.
- Participants will learn about the various disciplines within engineering.
- Teachers will develop pedagogical skills for implementing engineering-based activities with their own students.

Teacher Workshop

Math and science teachers from local middle, junior high, and high schools were invited to campus for a workshop. As shown in Table 1 below, the workshop was designed to last approximately 3 hours and was staffed by a team of faculty and students from the School of Engineering at Western New England College.

Table 1 – Schedule for Teacher Workshop

Time	Topic
4:00 PM	Sign-in, Pre-surveys
4:15 PM	Introduction to Engineering
4:45 PM	Design Activity: Earthquake-Proof Buildings
5:45 PM	Break
6:00 PM	Discussion Session
6:15 PM	Tour of Engineering Facilities
6:45 PM	Post-surveys
7:00 PM	Workshop End

After completing pre-activity surveys, participants listened to a brief presentation that provided an overview of the field of engineering, including an introduction into the various disciplines. Subsequently, the teachers participated in a design activity that allowed them to role-play as engineers. At the conclusion of the design activity, a discussion session was conducted in which the participants received information and materials to aid them in the implementation of similar design-based activities in their own classrooms. Finally, the teachers were given a brief tour of the engineering facilities on campus. The workshop was completed with post-activity surveys.

Student Workshop

The student workshop was conducted by a team of faculty and undergraduate students who traveled to a local high school. The participants were 11^{th} and 12^{th} grade students from Physics courses. Prior to the workshop date, pre-activity surveys were administered to the high school

students by their teachers. At the beginning of the workshop, a presentation was given to introduce the field of engineering. Next, the design activity was implemented, which was followed by a brief discussion of the results. The workshop closed with students completing post-activity surveys. As shown in Table 2 below, the workshop was designed to run for 1 hour.

Table 2 – Schedule for Student Workshop

Time	Topic
1:00 PM	Introduction to Engineering
1:10 PM	Design Activity: Earthquake-Proof Buildings
1:50 PM	Discussion
1:55 PM	Post-surveys
2:00 PM	Workshop End

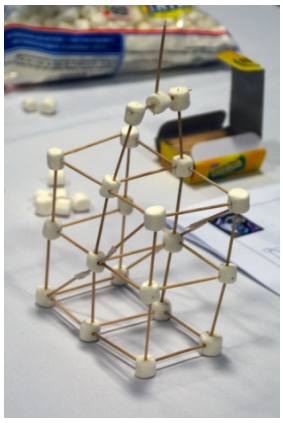
Design Activity

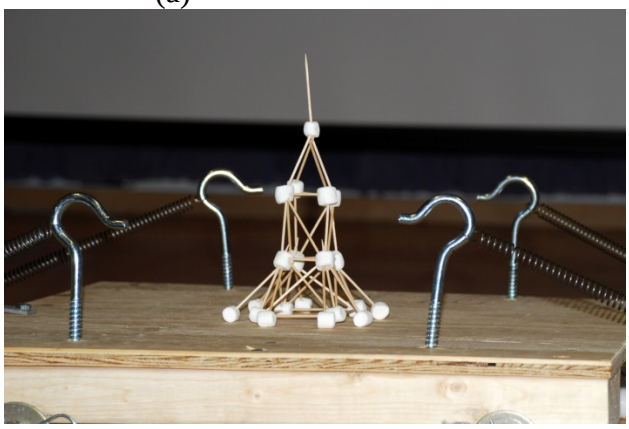
The centerpiece of both workshops was the design activity in which the teachers and students participated. The goal of the activity is to allow participants to experience the nature of engineering work by designing a solution within constraints, testing their solution, and making design changes/suggestions as a result of their testing. The activity is intended to be fun and challenging within an exciting environment that is created by the engineering students and faculty members that are staffing the program.

The activity involves designing a structure to withstand a simulated earthquake, as shown in Fig. 1. The participants were given a set of supplies to use during the construction of their building. The supplies included items to be used as beams/supports (e.g. toothpicks), joints (e.g. marshmallows), and adhesive (e.g. tape). During the teacher workshop, the participants worked individually, whereas the students worked in teams of 4 during the student workshop. Using the limited set of materials, participants designed and built a structure that was placed on a "shake table" to test its resistance to vibration. The goal for each participant or team was to make the tallest structure that can remain intact for the longest period of vibration on the shake table. Additionally, since each material had an associated unit cost, the designs were evaluated for cost-effectiveness.

Each participant first made a sketch of their design on a worksheet, which was then approved by a faculty/student facilitator. The participants then proceeded to build their designs using the materials they had selected. After the design period was completed, each participant or team brought their design to the front of the room to be tested on the shake table. The results were then tabulated regarding the height of their structure, resistance to simulated earthquake (i.e., time to failure), and cost-effectiveness. After the testing phase was completed, a discussion was held in which the participants made suggestions regarding changes they would make to their designs in order to improve performance.

(a)





(b) (c)

Fig. 1. Photographs from the teacher workshop: (a) participants building their structures; (b) completed structure; (c) structure during testing on shake-table.

Results and Discussion

In order to evaluate the impact of the workshop on the teachers and students, the participants were provided with a pre-activity survey and a post-activity survey. The intent was to obtain objective comparisons of the participants' pre- and post-workshop self-reported knowledge, level of interest, and comfort level in teaching (for the teacher workshop) or learning about (for the student workshop) engineering topics. The survey was comprised of three (3) questions that were structured based on a Likert scale. Each question consisted of four (4) potential responses that ranged from the most positive response (assigned a value of 4) to the least positive response (assigned a value of 1).

Since the intent of the teacher workshop was to reach a small number of teachers who could then impact a larger number of students, the sample size of data, reflecting the number of participants, was only three. As a result, standard statistical analysis of the data, such as a paired t-test, would not provide significant validity. Instead, a descriptive statistical analysis was performed using the mean assessment response comparison (pre and post activity). The results of such comparisons are shown in Table 3 below.

Table 3 – Pre and Post Mean Assessment Comparisons for Teacher Workshop

Question	Mean Response (Pre)	Mean Response (Post)
1	3.00	3.00
2	4.00	4.00
3	3.33	3.33

The mean response comparisons reflect no difference among the attendees' responses on the pre- and post-activity survey, which asked them to rate their knowledge of engineering disciplines, as well as their level of interest and comfort level in teaching engineering topics in their own classes. As a result of the limited sample size, it is indeed quite difficult to make any educated conclusions about the teachers' attitudes and interests in teaching engineering topics with their own students. It should also be noted that this was not a random sample of teachers, but rather a group that had sufficient interest in engineering to attend a three-hour workshop. However, an additional question on the post-assessment survey, which prompted the teachers to provide comments relevant to what they liked about the workshop, may offer more meaningful insight. Such comments included: "the activity was very practical, something I can use in my class", and "the activity, the constraints, the project ideas." These responses provide anecdotal evidence of the success of the workshop program. The teacher workshop was developed with input from the Department of Education at Western New England College to allow teacher participants to earn 3 credits toward continuing education. Thus, in addition to the benefit provided from an educational standpoint, the program may help teachers in their efforts to reach their professional goals of certification and/or recertification.

With regard to the students' survey results, a larger sample size ($n = 23$) was obtained, thus inferential statistics were used to study the responses to each of the three questions. For question #1, the responses were significantly higher on the post-activity survey than the pre-activity survey ($p = .009$). In other words, the shake table activity did in fact increase the students' overall knowledge of engineering applications. On the other hand, the students' responses to questions #2 and #3 were insignificant ($p = .517$ and $p = .481$, respectively). This indicates that the interest and comfort level of the students for the engineering discipline did not significantly improve as a result of the design activity. When prompted on the survey to provide comments about what they liked about the activity, student responses included: "very interesting and fun," and "the chance to try different designs on earthquake testing." Overall, it can be surmised from the pre- and post-activity surveys that the workshop increased student knowledge of engineering topics, but it did not cause an immediate increase in student interest in pursuing engineering as a career of choice.

The outreach effort described in this work is inherently sustainable as the skills and activities to which the teachers are exposed can subsequently be transferred to their students over the course of several years. Additionally, the major take-away from the program is not the shake-table activity itself, but rather the type of activity that was performed, namely the design of a solution within constraints in a fun, competition-based environment. Thus teachers can easily adapt this

approach to a wide range of activities that will be suitable for their particular classroom topics and grade level.

In addition to the benefits provided to participants, the workshop also had several other broader outcomes. Undergraduate students were involved throughout the development of the workshop, including the construction of the shake table. This afforded opportunities for mentorship by the engineering faculty in areas that are often difficult to address in undergraduate programs, such as project management. Furthermore, by being directly involved in the workshop as facilitators, the students were given their own opportunity to serve as mentors for the participants. This early exposure to mentorship may foster skills that will become an important part of their future careers since the students will eventually serve as mentors for the next generation of engineers. Moreover, during the post-activity discussion the students were exposed to contemporary issues facing the K-12 education system, which may serve as a catalyst for their future involvement in the education community as contributors and educators.

Conclusions

Due to the success of the initial program, it is expected that the described workshop will continue to be used on a regular basis at Western New England College. Additionally, it is anticipated that other institutions could adopt or modify the workshop to conduct similar outreach efforts in their own communities. Since the major goal of the workshop is to give participants the opportunity to role-play as engineers, the design activity can be readily changed to suit the interests of particular groups of faculty, students, and teacher participants, thus serving as a framework for multi-year outreach activities.

Bibliography

[1] K.P. Wardlow and W. Misiolek, "Lehigh University Program Reaches out to High and Middle School Students," *Advanced Materials & Processes*, Vol. 161, No. 10, p. 72, 2003.

[2] M.Z. Jimenez, L. Salas-Morera, A. Cubera-Atienza, and M. Varo Martinez, "An Outreach Project For Engineering Education," *IEEE Transactions on Education*, Vol. 53, No. 1, pp. 96-104, 2010.

[3] M. Yilmoz, J. Ren, S. Custer, and J. Coleman, "Hands-on Summer Camp to Attract K-12 Students to Engineering Fields," *IEEE Transactions on Education*, Vol. 53, No. 1, pp. 144-151, 2010.

[4] Author unknown, "Girl Day Takes on New Urgency," *Professional Safety*, Vol. 51, No. 1, p. 24, 2006.

[5] M. Hunter, "Opportunities for Environmental Science and Engineering Outreach Through K-12 Mathematics Programs," *Environmental Engineering Science*, Vol. 23, No. 3, pp. 461-471, 2006.

[6] J. Musto, W. Howard, and S. Rather, "Using Solid Modeling and Rapid Prototyping in a Mechanical Engineering Outreach Program of High School Students," *International Journal of Mechanical Engineering Education*, Vol. 32, No. 4, pp. 283-291, 2004.

[7] R. Habash, "Engaging High School and Engineering Students: A Multifaceted Outreach Program Based on a Mechatronics Platform," *IEEE Transactions on Education*, Vol. 53, No. 1, pp. 136-143, 2010.