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Enhancing Diversity through Explicitly Designed Engineering Outreach

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The Engineering Place at NC State University was founded in 1999 and grew as an extension of the Women in Engineering Program with the desire to attract more women to engineering by reaching out to younger students. It was soon evident that any efforts to attract women to engineering would also be beneficial for underrepresented populations and all students. Working in the preK-12 space also highlighted the need to inform the public about the true nature of engineering, to promote and support educational improvements in the way that math and science are taught in K-12 schools and to place importance on 21st century skills for all students. Using these dual goals as a starting place, the outreach programs grew to serve more than 15,000 students and 2,000 teachers face-to-face each year.

University outreach in engineering is not uncommon, but the techniques used to scaffold success in meeting diversity goals are not obvious and not always discussed. This paper will describe the research-to-practice design approach of a comprehensive outreach program, making the elements designed to enhance the appeal of engineering to a diverse audience explicit. As an example, a common activity used in engineering outreach is building a robot. Because this might be construed as appealing more to male students, some groups might, instead, propose an activity to design high heeled shoes. The outreach program described in this paper seeks to design activities that are neither male NOR female linked, that use authentic constraints and relate to real-world problems. Other examples included in the paper will be how programs are advertised, budgetary considerations in low socioeconomic areas and more. This approach to preK-12 outreach has contributed to a sharp increase in the diversity of a large College of Engineering.

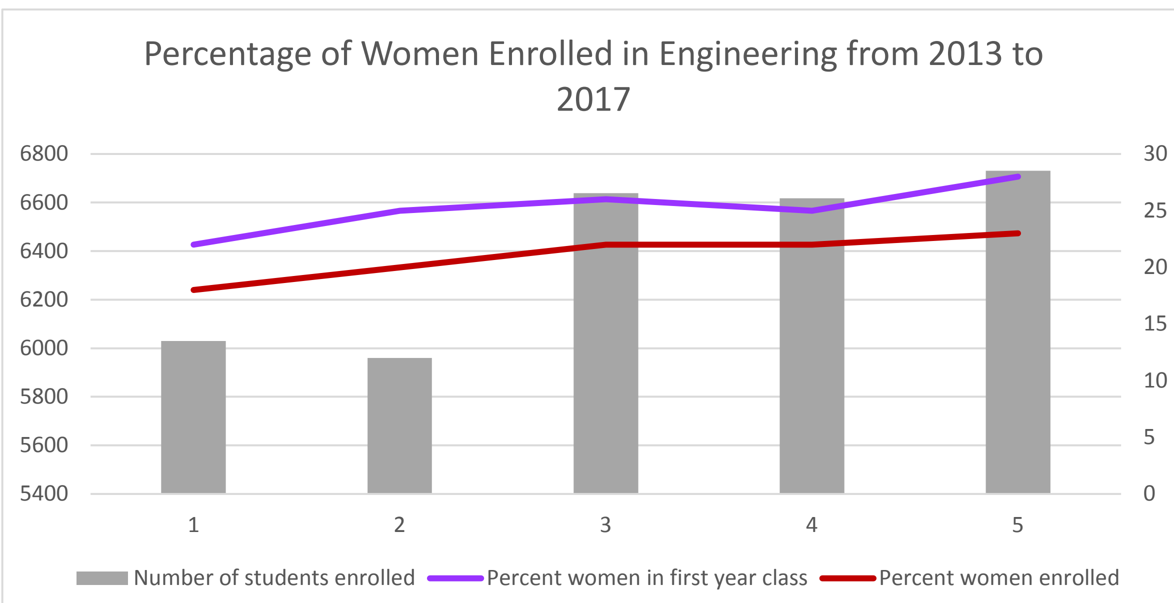
Research basis

The Engineering Place, the K-12 engineering outreach program at North Carolina State University, grew out of an initial effort to increase the representation of women in the undergraduate population. Gender diversification was not the only goal of the program. Ethnic and socio-economic diversity are also major goals. In addition, the access for students with a wide range of disabilities to engineering as a potential career was an important priority. When setting out to design an approach to engineering outreach, these goals might appear to be conflicting. One might conclude that separate programming would be necessary, such as engineering camps specifically for girls or a day on campus specifically for blind students. These types of efforts have their place, but how does one balance them with programming that is open to students who do not fit the particular categories. After all, a program for white boys exclusively makes no sense, and a part of the diversification of an over- all population should be different populations working together.

Engineering outreach programs have been around for quite some time, with a casual survey indicating that the late 1990’s saw an uptick in the number of programs, perhaps due to increased NSF funding. In the same time period, efforts to recruit more women to engineering were languishing. The nationwide percentage of women has hovered in the vicinity of 18% for over 20 years [1]. Coincident with these phenomena, research emerged providing good insight into characteristics of educational programming that appeal to girls. SciGirls published the SciGirls Seven [2] strategies for engaging girls. They advise providing activities that allow for collaboration and that are personally relevant to the participants. In addition, they advise encouraging the girls to think critically and providing opportunities to interface with role models and mentors. And this is just one example of solid, research-based insight.

The argument can be made that we KNOW what to do to interest more girls in engineering, but the research-to-practice link is somewhat tenuous. The outreach program at a large, public College of Engineering has been molded to address best practices supported by research.

Program assessments yield positive results, but, most importantly, the outreach program taken as a part of a Women in Engineering portfolio is now partially credited with a first year engineering class that is 28% women, despite a sharp growth in total enrollment. The figure below shows the increase in percentage of enrolled women in engineering, compared to the total number of engineering students enrolled.



Program Design Elements

The program has several constituent elements, such as school visits, campus visits, Family STEM nights, museum programs, an extensive array of summer camps, Girl and Boy Scout programming, and several other elements. Each of these disparate programs draws from a common reservoir of activities and ascribe to common design criteria, that are all based on research aimed at interesting girls in STEM. At the same time, the programs are also held to the expectation that they will not discourage boys. Table one summarizes design elements and related research outlined below.

Activity Design

Activities are either selected from sources such as Teachengineering.org [3] and adapted or invented at need. The activities used are a broad array that will deliberately cover multiple engineering fields. The topics are chosen to be generally appealing. They are also designed to be relevant to the age of the student participating. Another focus is to ensure that the activities are not proscriptive. In other words, the activity does not consist of building an artifact according to specific instructions. Not only does this not appeal to girls to the same degree [4], but it is also not truly engineering! For example, if a goal of the activity is to teach how to assemble a series circuit with a LED, the activity might be to design a desk lamp that would allow you to have enough light to read if the classroom lights went out. Topics for activities are taken from current events, popular technology, and even university research labs. This leads to the development of units such as self-folding shapes, based on research by Drs. Michael Dickey and Jan Genzer [5]. In this activity, students, in grades K-2 inscribe a pattern in black on a plastic sheet, and then expose the cut out pattern to heat. The sheet then folds along the darker lines. Students learn about mathematical shapes in two and three dimensions, practice spatial visualization and design a container for a small toy.

A similarly research-based activity (for children in grades K-2) is the design of a maze for a Hexbug nano. Students are given requirements (such as include a hill, a tunnel, certain numbers of turns of specific degree measurements, etc.) to incorporate into their maze. The students work in groups to produce a maze from recycled materials and demonstrate their mazes to each other in a gallery walk. The same characteristics of the hexbugs that make the maze design interesting are used in research with biobiotic insects. [6] Such biobiotic insects are used for search and rescue in disaster situations.

Wearable electronics are a major focus of the ASSIST Engineering Research Center at the university, and they make an excellent source for activities for older students. Students use Adafruit Gemma or Floras, conductive thread, and LEDS to design a pattern of flashing lights on cloth or a headband (such as cat ears near Halloween). Such wearable electronics are easily available and inexpensive for small numbers of students, and research in this area is leading to medical monitoring applications with life-saving results.

Each of the three activity examples discussed above require creativity and collaboration and allow students to approach projects in their own way, key elements of the SciGirls report [2]. They are also directly linked to real-world engineering projects that have clear difference-making applications which reports such as Changing the Conversation [7] have found are important to girls. But these applications are also appealing and important to boys. They do not encourage any dichotomy between genders, but appeal to ideas and practice of inclusivity.

Examples of activities that are closely relevant to daily life include diaper dissection, where students take apart different types of diapers and try to determine which of the components differentiate the performance of the diapers. They also measure how much water each diaper can hold, of course. Another activity has students design a bilirubin incubator for a doll that uses blue LEDs. These activities clearly require critical thinking and are relevant to many of the students who have younger brothers and sisters.

Program Design

Programs are conducted with a variety of types of staff. The less complex programs (campus visits, museum presentations) are conducted by Outreach Ambassadors. These are engineering students who are hired and trained to conduct outreach activities. The students self-select, and are generally a high percentage female and ethnic minority. They are trained in guiding younger students through inquiry, being a role model, and assorted safety topics. Careful training is an important element in the success of the programs. [8] The K-12 participants engage readily with the engineering students, who become de-facto role models.

More complex programs, such as summer camps, have a tiered mentoring structure. Teachers are paired with engineering students with a group of approximately twelve K-12 students (grouped by age: K-2, 3-5, 6-8, 9-10 and 11-12). High school interns provide support to the teacher/engineering student teams. The whole group is trained and advised by engineering faculty. Extensive training is provided to the teachers and engineering students in questioning strategies, guiding inquiry and open-ended design. [9] An important feature of the camp design is to make explicit and purposeful connections to the students' experiences and curriculum in their formal education, ascribing to the theory of additive learning [10]. This provides a continuity of learning and ties the new activities to the students' own experiences.

Finally, programs are designed with inclusivity of students with disabilities in mind. Activities that involve light (such as LEDs) have buzzers and sound as alternatives to include students with sight challenges. Activities that involve sound, such as designing a speaker, include ways of visualizing the sound, such as using cups with balloons stretched across and salt on top that will vibrate. Students with Autism spectrum-related disabilities are placed on smaller teams and given quiet work spaces and assigned college mentors. All of the programs are designed to be maximally inclusive.

Conclusion

The programs offered by the university outreach department are evaluated on the goals of attracting a diverse population, providing an overview of engineering and its many areas of expertise, always highlighting the true nature of engineering through the Habits of Mind, improving students' attitudes towards learning in STEM disciplines, improving teacher's attitudes towards teaching in STEM disciplines, and recruit future engineering students to engineering. [11]

The overall goal of supporting diversity is accomplished through a variety of research-based techniques. The initial, primary goal of appealing to girls remains, but the very same techniques that appeal to girls promote maximum inclusivity, which is itself appealing to girls.

Summer camps are 30-50% female and other programs are either 50/50 male/female or majority female (for example, girl scouts). The only exception is occasional boy scout programs, but these programs are also delivered by majority female engineering students and faculty.

The engineering first year class at the university has seen the benefit of a growth in female populations, growing in number to 1500 students per year and in percentage female, from 14% in 2004 to 28% in 2017. This growth cannot be definitively tied to the engineering outreach program, but the correlation is highly suggestive.

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