

## **Unique Extracurricular Program Recruits Women into Engineering Through Orthopaedic Biomechanics**

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# UNIQUE EXTRACURRICULAR PROGRAM RECRUITS WOMEN INTO ENGINEERING THROUGH ORTHOPAEDIC BIOMECHANICS

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## Introduction

Over the past twenty five years, the government and industry have called for heavy investment in Science, Technology, Engineering, and Mathematics (STEM) education and developed an impressive array of classroom and extracurricular programming designed to encourage young people to pursue STEM careers <sup>[1,2]</sup>. Despite these efforts, the vast majority of college-bound high school students continue to pursue majors outside of engineering and other STEM fields <sup>[3]</sup>. Furthermore, there are high attrition rates – some approaching 50% - for students initially entering as engineering majors <sup>[4,5]</sup>, with both climate and lack of context for the broader impact of the field being cited as reasons for attrition. The retention rates are even bleaker for underrepresented groups in engineering, such as women and minorities <sup>[6,7]</sup>. Over 50% of women graduates with professional engineering degrees leave the field within 5 years <sup>[8]</sup>, and, in some part, narrow job focus, lack of creativity, and minimal societal impact of the profession have been cited as deterrents for recruitment and retention of young people in the engineering <sup>[9,10]</sup>. As a field, it remains essential not only to recruit the highest caliber of students but also to keep these students in the field.

Engineering, as a discipline, is in the middle of a much-needed public relations makeover to “change the conversation” about engineering practice and refocus engineering education around “grand challenges” <sup>[15]</sup> with direct and immediate societal impact. The National Academies of Engineering, which is leading the effort to rebrand engineering, emphasizes the need for new programing in engineering education to including messages such as: “Engineers are Creative Problem-solvers” and “Engineering is essential to our health, happiness and safety”<sup>[15]</sup>. The field of orthopaedics is uniquely positioned to provide concrete examples of both of these statements and more. This subfield involves the study of the human body as a machine, and has direct application to medical device design as well as musculoskeletal disease diagnosis and treatment. Engineers from an array of disciplines, including mechanical, electrical, chemical, and bioengineering, work in orthopaedics, and the field is particularly attractive to women and minority students, who tend to be drawn to fields with a greater degree of direct societal impact <sup>[10,14]</sup>.

Unfortunately, orthopaedics has diversity problems of its own. Neither the clinical nor non-clinical sectors in orthopaedics are gender diversified, with only 7% of board certified orthopaedic surgeons <sup>[11]</sup> and 11% of the mechanical engineering workforce, which designs and manufactures orthopaedic implants, being female <sup>[12]</sup>. The earliest “leak” in the pipeline for women in orthopaedics is in their choice of college major, with only 9% of qualified female

college applicants choosing to pursue biosciences and 5% pursuing engineering<sup>[3]</sup>. Early exposure to the field and successful women role models are key to recruiting talented women to orthopaedics<sup>[13]</sup>, and these young women are much needed if the field is to retain its competitive advantage over other medical subspecialties in terms of the talent of its workforce.

One method of providing such experiences for young women is through extracurricular activities during which practicing women engineers and clinicians may act as both instructors and early career mentors to women on the verge of making these critical career decisions. Since 2009, our organization, governed by practicing women engineers and surgeons, has conducted out-of-school time programs across the country for women high school students to expose them to careers in engineering and medicine through the lens of orthopaedic surgery and medical device design. The purpose of this study is to evaluate the effectiveness of our ongoing nationwide programming effort in recruiting and retaining women in under-represented areas of STEM, particularly engineering. Our program is unique in terms of the subject matter, the hands-on approach to administering its curriculum, and the focus on peer mentoring and high achieving female role models. If effective, this program may be used as a model for other out-of-school-time programs focused on recruiting diverse talent into the engineering pipeline.

## **Methods**

We implemented a day-long, extracurricular outreach programs for high school women that focuses on career exposure to engineering and medicine through the lens of orthopaedic surgery and medical device design. The program has been operating continuously since 2009; and it has grown from a single program location with 12 participants in 2009 to 32 locations with 969 students in 2014. Every program is held on-site at either a medical center or a university with a healthcare affiliation or medical school. All participants are female high school students, with most being in their junior or senior year; and the programs are staffed by a predominantly female volunteer corps of practicing engineers, engineering students, medical students, and clinicians (orthopaedic surgeons, physical therapists, and general practitioners). Each program can accommodate up to 40 students. Students are recruited through STEM non-profit affiliates, e.g., Project Lead The Way, Girl Scouts, and via social media and contacting large, urban school districts. Students apply online through the program's website and are selected based on the quality and composition of two essays. Academic performance, e.g., GPA, class rank, or AP coursework, is purposefully not considered in the application. Racial information is collected at the time of application; however, it is blinding during the selection process and only analyzed after students are notified of their acceptance to the program. Results of these racial demographic data, collected from 2012 to present, show program participants are 13% African American and 14% Hispanic, with 45% Caucasian and 21% Asian.

Program curriculum is standardized and consists of approximately two hours of interactive lecture and roundtable discussions from women orthopaedic surgeons, high level administrators and businesswomen, and practicing engineers in the biotech field. Each lecture is approximately 30 minutes long, and speakers are encouraged to intersperse personal experiences and challenges with technical content during their lectures. Issues such as work-life balance, career pathways and training, and challenges faced by females in underrepresented professions are explicitly discussed. The curriculum also includes four hours of hands-on activities, specifically mock orthopaedic surgeries and biomechanics experiments with high-fidelity plastic bone models. These activities, which include assembling an external fixator, designing and installing an intramedullary nail, and practicing arthroscopic ACL reconstruction, were custom

designed by our organization to provide age-appropriate, contextual experiences with surgery and engineering practices.

To assess the impact of the program, all alumnae from 2009 to 2014 with active email addresses (N=2524, approximately 98% total alumnae) were surveyed, as well as a control group of students who were waitlisted, rejected, or no-shows to the program (N=2216). For the control group, most students were waitlisted or rejected due to program capacity at specific program sites. Surveys were distributed by email using online software (Qualtrics v0.248s), and the collection period was two weeks in May 2015. Both program alumnae and control students were administered identical survey questions related to their career trajectories since high school (for college and post-college age students) or in high school (for students still in high school). Program alumnae also answered additional questions about the impact of the program on their interest in STEM and medicine, as well as perceptions of these career pathways and self-perceptions of abilities and confidence to pursue these careers. Responses for student career outcomes were distilled into rates of recruitment and retention at various stages in the STEM and orthopaedic surgery pipeline, e.g., matriculation to college or medical school; and these outcomes were compared between program alumnae and controls using chi-square test for independence. Questions regarding program impact were rated on a 5-point Likert Scale and presented qualitatively for the program alumnae group only.

## Results

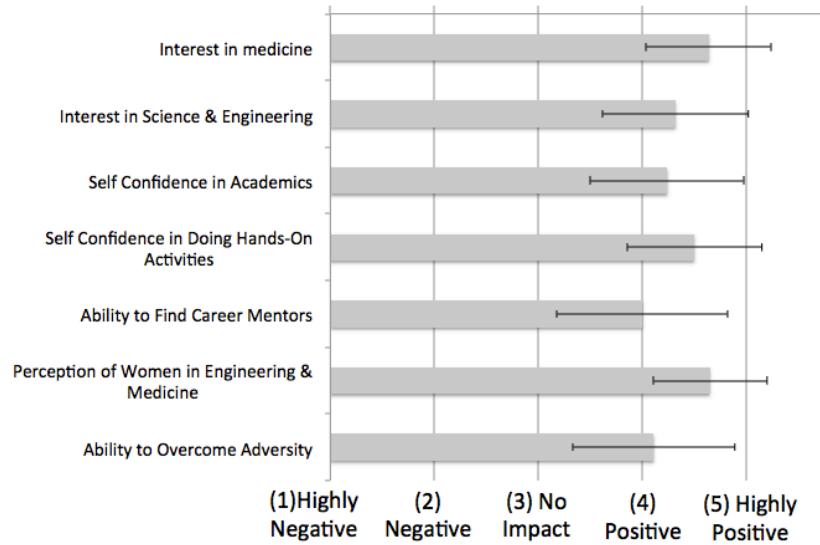
There were 793 program alumnae respondents (31.4% response rate) and 196 controls (8.8%). Alumni respondents were representative of the overall program alumnae population in terms of grade level at the time of the program (Mode: Grade 11) and geographic distribution. The current educational level of program alumnae is predominantly upperclassmen (11<sup>th</sup> or 12<sup>th</sup>) in high school (53%) and underclassmen (Freshmen, Sophomore) in a 4-year college (32%), with ten (10) alumnae post-college (6 in medical school, 3 in the workforce, and 1 in college). The control respondents were skewed towards younger students who were recently waitlisted or rejected due to program capacity. 30% of the controls were underclassmen in high school; 58% were high school upperclassmen; and 12% were in college.

Alumnae reported that the program had a positive effect on their interest in medicine, self-confidence in hands-on tasks, and perception of women in engineering and medicine (Figure 1). There was no difference in these outcomes between alumnae who have matriculated to college and those still in high school ( $p>0.05$ ).

The career trajectories of program alumnae are as follows (Table 1). Of those survey respondents who are still in high school, 98% plan to enroll in a 4-year college or university, and 97% intend to major in STEM, with 32% in engineering and 81% biology or bioscience (multiple selections permitted). There are similar findings for the alumnae who are presently in college. 100% are enrolled in 4-year programs, with 93% in STEM majors; 64% are biology or biosciences; and 23% are engineering majors. 56% of the alumnae in college are intending to go to medical school, and 23% are “very interested” in pursuing orthopaedics as a career choice. For the 6 alumnae presently in medical school, 5 are “very likely” (n=2) or “likely” (n=3) to pursue orthopaedic residency.

Despite the relatively small sample size of the control population, there were some differences between the program alumnae and control groups (see Table 1). Amongst the high school respondents, the control group was more likely to be undecided on a college major compared to program alumnae (32% controls vs. 23% alumnae,  $X^2(1, N=627)=4.57, p=0.04$ ). For

respondents who are currently in college, there was a trend for a greater percentage of program alumnae to major in engineering (23%) compared to controls (8.3%) ( $X^2(1, N=324)=3.39$ ,  $p=0.07$ ).



**Figure 1:** Responses from all program alumnae in the follow-up survey to the question “Did your experience with [the program] have an impact on you in the following areas?” Responses correspond to 5-pt Likert Scale. Whiskers represent  $\pm 1$  standard deviation.

**Table 1:** College majors for program alumnae and controls for both high school (intended major) and college (actual major). Students were permitted multiple responses to reflect dual majors and interdisciplinary areas of study. Choice of college major was compared between alumnae and controls using chi-square test for independence ( $df=1$ ,  $N=627$  for high school,  $N=324$  for college).

College Major	High School			College		
	Program	Control	p value	Program	Control	p value
Physics, Chemistry, Math	29.4%	30.8%	0.68	7.3%	8.3%	0.86
Biology or Biosciences	80.8%	83.7%	0.15	64.3%	66.7%	0.82
Engineering	31.7%	26.7%	0.21	23.0%	8.3%	0.07
Liberal Arts	6.0%	5.2%	0.60	7.0%	0.0%	0.07
Fine Arts	6.8%	7.0%	0.74	0.3%	4.2%	0.10
Humanities	9.9%	13.4%	0.38	1.7%	8.3%	0.09
Business	8.5%	9.9%	0.92	4.7%	8.3%	0.46
Allied Health Sciences	4.4%	4.7%	0.69	6.3%	12.5%	0.29
Other	0.8%	0.0%	0.24	0.7%	0.0%	0.58
Undecided	23.0%	32.0%	0.04	0.7%	0.0%	0.58

## Discussion

These results strongly suggest that our outreach program is effective in recruiting and retaining women in the STEM pipeline, particularly engineering and pre-medicine, and that the impact of the program on student participants is immediate and sustained through matriculation to college. Our program alumnae are entering college engineering and bioscience programs at rates approximately four times the national average [3]; and these students report that the program had a sustained, positive effect on their self-confidence in hands-on tasks and perception of women in engineering.

The effectiveness of our outreach program in recruiting and retaining women in STEM can be attributed to several attributes. First, the program curriculum is designed to be “sticky” – that is, to immediately engage the student through hands on activity and to plant the desire to continue to interact with the subject matter through interactions with older role models who have pursued careers in orthopaedics. During the one-day program, lectures are brief and student-focused, leaving ample time for hands-on workshops. The workshops allow students work in small groups to perform real-world tasks, e.g., surgical simulations and biomechanical tests, with actual medical devices and tools; and they are guided through these workshops by practicing women surgeons and engineers. Second, although the curriculum is technically complex, our organization has developed the logistical infrastructure necessary to scale up our outreach programming efforts to sites nationwide while maintaining program effectiveness and consistency. This is accomplished by centrally administering student recruitment and program evaluation and providing on-site content and logistical support and volunteer training by our staff at all of our program locations.

Although these results are certainly positive, there are some limitations to the study that should be addressed. First, the admission process for our outreach program, which is based entirely on student essays, is biased towards students who already show an interest in STEM subjects. This bias is intentional, as our organization’s limited resources are focused on directing high school age women into under-represented STEM disciplines and specifically engineering. We addressed this intentional bias in this study by soliciting a control group of equally well-qualified STEM-inclined females, most of who were wait-listed for our program due to capacity limitations. Relative to this control group, program alumnae demonstrated nearly triple the rate of matriculation into engineering majors in college. A second limitation of our study is that the alumnae and control surveys were optional, which may have induced bias towards students who are pursuing careers aligned with the organization’s focus on STEM broadly, and engineering in particular. However, our response rates were very high for a voluntary survey (31.4%), particularly for participants in one-day exposure program at up to 5-years follow-up. Furthermore, if there were survey participation bias, we would expect it to equally impact both program alumnae and control cohorts, thus not affecting the relative outcomes of these two groups.

In conclusion, these results provide strong evidence that our unique extracurricular outreach program is effective at recruiting and retaining high school women in STEM, broadly, and engineering in particular. Program curriculum and messaging well align with nationwide engineering education and diversity initiatives [15], specifically, “Change the Equation” and “Grand Challenges of Engineering,” and may prove an interesting case study demonstrating the effectiveness of these initiatives in an extracurricular program setting. Based on our positive findings, we suggest that our program be used as a model for other programs focused on diversifying the engineering talent pipeline.

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