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Pre-College Engineering Participation Among First-Year Engineering Students

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George Dante Ricco is a recent graduate of the School of Engineering Education at Purdue University and is on the job market. His work focuses on applying various research methods to address long standing anecdotal questions, ranging from ethnographic studies to hierarchical linear models. He was born in Kent, Ohio. He attended Walsh Jesuit High School, and instead of becoming a Jesuit, he decided to go to Case Western Reserve University in Cleveland to obtain his BSE in engineering physics (2002). He then spent a number of years on the beach at the University of California at Santa Cruz, receiving master's degrees in physics (2007) and earth and planetary sciences (2008) until emancipated by Prof. Matthew Ohland at Purdue University. He enjoys cycling, weightlifting, running, photography, volunteering at a number of organizations, and the untold intellectual pleasures provided by the study of Lagomorph physiology. He resides in Lafayette, Indiana, and in-between job interviews spends time with his Leporidae life partner, Rochelle Huffington Nibblesworth.

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Abstract

In recent years, engineering content is increasingly appearing in the K-12 classroom. As pre-college engineering programs grow, first-year engineering students are arriving in university engineering programs with significant prior exposure to engineering content and practices. In this paper, we present the results of a survey of first-year engineering students on their participation in pre-college engineering programs and activities. Students enrolled in four sections of a first-year engineering program at a large public university were asked to complete a survey indicating the settings where they encountered engineering prior to college, named and described the various activities that they participated in and the approximate amount of time they spent doing each activity. Participants also provided demographic information.

Results indicate that 89 percent of domestic students enrolling in first-year engineering classes at the university have experiences they describe as engineering prior to college. High school classes are the most common way that students are exposed to engineering content by a significant margin, followed by extra-curricular activities, summer camps or programs, and middle school classes. While the majority of respondents reported participating in one or two different activities, some reported participating in as many as nine different pre-college engineering programs or activities.

Background

The National Academy of Engineering report *Engineering in K-12 Education – Understanding the Status and Improving the Prospects*[1] identifies five main benefits of K-12 engineering education. These are 1) improved learning and achievement in science and mathematics, 2) increased awareness of engineering and the work of engineers, 3) understanding of and the ability to do engineering design, 4) interest in pursuing engineering as a career, and 5) increased technological literacy. This study focuses on pursuing engineering as a career, which typically requires a 4-year college degree in engineering. While the other benefits of K-12 engineering are starting to be explored,[2] studies on the effect of K-12 engineering programs on university success remain limited.

Numerous venues exist for exposure to engineering prior to matriculation in a college engineering program. Elementary engineering programs such as Engineering is Elementary aim to reinforce students understanding of mathematics and science via simple engineering design projects.[3] Students can further explore engineering concepts in middle school classes, and study discipline-specific content or complete a capstone design project as part of a high school class or curriculum like those developed by Project Lead The Way[4] or the International Technology and Engineering Educators Association.[5] Outside of a formal class setting, numerous other opportunities exist for students to explore engineering. These include after school or extracurricular engineering activities like robotics clubs or design competitions such as FIRST robotics.[6] Many universities sponsor a variety of outreach activities to engage students in engineering, as well as engineering-themed summer camps.

Despite the growing prevalence of pre-college engineering programs and increasing acceptance and integration of engineering content at the K-12 level, relatively little research has been done on the lasting effects of participation in these programs on students who choose to pursue further study in engineering. Participation in pre-college engineering classes has been positively associated with engineering self-efficacy,[7] and research on the effects of participation in Project Lead The Way suggests that students are more likely to pursue STEM degrees and, in limited circumstances, may have higher GPAs than students who did not participate in these classes.[8]

K-12 and higher education institutions both need information on the effects of pre-college engineering programs on undergraduate engineering students. The persistence and grades of students that have participated in K-12 engineering programs and continued on to study in college engineering programs are possible measurable outcomes of K-12 engineering education programs. The NSF, the Department of Education, many state governments, and private foundations collectively invest many millions of dollars in engineering education and outreach at the K-12 level, resulting in increasing numbers of incoming engineering students arriving on campus with prior exposure to engineering. Understanding the effect of these programs on university experiences would help guide higher education faculty and administrators in providing the best experience for those students and helping them to be more successful in STEM pathways.

Research Questions

1) How prevalent is participation in pre-college engineering activities among first-year engineering students?
2) Does participation vary between male and female engineering students?
3) What is the relationship between pre-college engineering activities and students' chosen majors?

Method

To explore these questions we developed a survey and administered it to a sample of first year engineering students at Purdue University. Based on existing research on the types of pre-college engineering programs,[1,2] we identified six different potential settings for pre-college engineering activities, described earlier in this paper. These include elementary school classroom, middle school classroom, high school classroom, extracurricular activity, summer camp, and university-sponsored pre-college engineering activity. We also provided an "Other" option for students who had experiences that they felt were relevant but did not fit into any of the predefined categories. For each category, the respondents could list up to four different activities, and for each activity they were asked to provide a name, a brief description of the activity, and the amount of time that they spent on the activity over the course of a year. Amount of time was reported in one of three options: one day/less than 10 hours, 10 to 40 hours, and over 40 hours. We chose these categories to allow us to distinguish between extended activities, weeklong activities, and single or limited contact activities. The respondents also indicated their first choice of engineering discipline and family members or friends who were engineers.

In addition to asking about their engineering experiences, we also asked students to provide demographic and background information. This included gender, race/ethnicity, number of semesters at the university, and high school zip code. International students were included in the survey, but analysis of their responses is beyond the scope of this paper.

We administered the survey online via Qualtrics, and sent an individualized link to the survey to all students who were enrolled in four sections of the first-year engineering class at Purdue University in the Fall 2013 semester. Prior research using this survey relied on self-selected respondents.[9] By comprehensively surveying all of the students in four sections of the first-year engineering course representing approximately one fourth of the first-year engineering population, we have a greater ability to draw conclusions about the first-year engineering population. Survey data were collected in class, with multiple reminder emails sent to increase the response rate.

Results to date

The survey link was sent to 470 students, with 411 students completing the survey for a response rate of 87%. Of these respondents, 301 were domestic students and used for the subsequent data analyses presented below. Tables 1 and 2 show the gender and race or ethnicity of the survey respondents, respectively.

Table 1: Gender of respondents (n=294)

Gender	Count	Percent
Female	76	26%
Male	218	74%

Table 2: Race/ethnicity of respondents (n=293)

Race	Count	Percent	Percent of First-Year Engineering Students
White	218	74%	80%
Asian	36	12%	7%
Hispanic/Latino	20	7%	5%
Multiple/Other	11	4%	N/A
Black/African American	8	3%	3%

Figure 1 shows the frequency of participation in different types of activities. High school classes were the most common place where students encountered engineering prior to university, followed by after school activities, summer camps, and middle school classes. Many students also indicated participating in a variety of other activities not covered by the survey categories. These were mostly internships or employment with engineering companies, but also included hobbies and individual projects. In total, 89% of the domestic students responding to the survey indicated participating in activities they felt were engineering prior to entering the first-year engineering program.

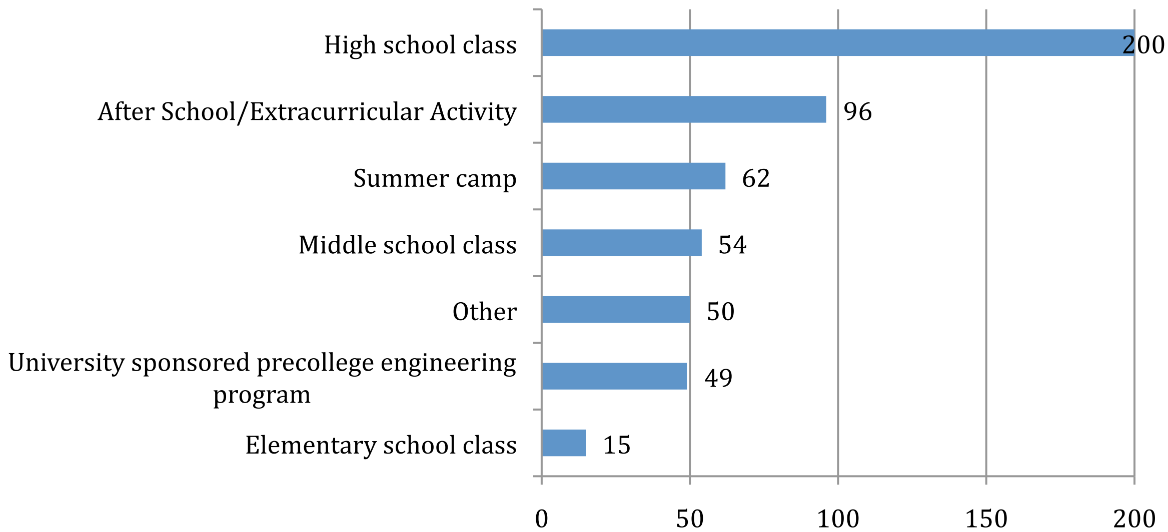

Figure 1: Frequency of participation in different types of pre-college engineering activities (269 of 301 reported participating in one or more activities, or 89%)

Figure 2 shows the number of pre-college engineering activities reported by all participants in the study. The majority of the respondents reported participating in zero to two activities, with nine being the highest number of activities reported. Figure 3 shows the same data, but with the results disaggregated by gender and expressed as percentages as opposed to counts. This shows some differences between the rates of participation in pre-college engineering programs between men and women. While 43% of men report participating in zero or one pre-college engineering activities, 59% of the women fall into these categories. The majority of women report participating in zero or one engineering activities, while the majority of men report participating in one or two activities. However, for three or more activities the rates of participation among women and men are fairly similar.

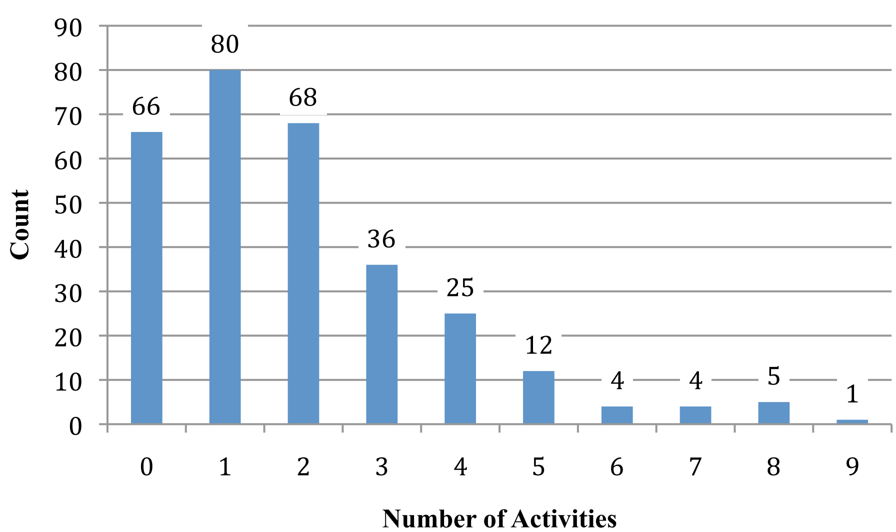

Figure 2: Number of activities per respondent

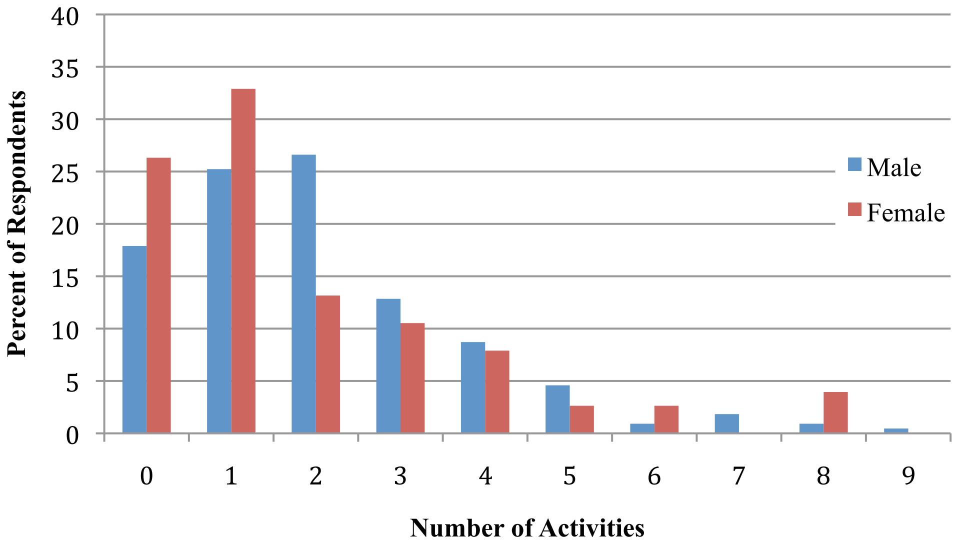

Figure 3: Distribution of activity counts by gender

Statistically speaking, the rates of participation for men and women are too similar for us to conclude that they are different. We compared overall mean and standard deviations of the two distributions, and although our N for both are lower than we would desire, both fit a Gaussian curve with kurtosis with low standard error. The mean, standard deviation, and standard mean error for men was 2.05, 1.74, and 0.12. For women, the same numbers were 1.83, 1.96, and 0.23. At first glance, these numbers are encouraging, but the means of both are within each other's standard mean error, thus, the two curves are not different enough to be considered separate standard distributions.

We also used a standard Z-test algorithm to calculate the differences between the distributions, and discovered that the value of the Z-statistic was -1.2. The absolute value of the Z-statistic is a measure statistical difference between two normal distributions. In this case, our Z-statistic shows that the distribution of men and women is not statistically different.

For the women, the low N coupled with a few strong outliers does throw the fit of a Gaussian distribution off by a noticeable amount. For instance, if we were to eliminate those women with activity count of 8, our mean would drop to 1.57 and our standard mean error would drop to 0.18 and leads to a larger absolute value of the Z-statistic of 3.3. With that in mind, the low overall number of women, the number of outliers, and the sensitivity to a Gaussian fit, lead us to conclude that we cannot determine at this time if the two distributions are statistically different.

Table 3 illustrates the relationship between number of activities and the intended major of the survey respondents, and suggests several trends. Respondents who participated in larger numbers of pre-college engineering programs and activities seem to be more likely to be interested in electrical and computer engineering and interdisciplinary/multidisciplinary engineering, and less likely to be considering majoring in industrial engineering, biomedical engineering, or agricultural engineering.

Table 3: Major and average number of pre-college engineering activities

Major (number of respondents)	Average number of activities
Electrical and Computer (37)	2.7
Interdisciplinary/Multidisciplinary (5)	2.4
Mechanical (81)	2.2
Nuclear (11)	2.2
Chemical (30)	2.1
Aeronautical and Astronautical (41)	2.0
Civil (18)	1.7
Biological and Food Process (6)	1.7
Undecided (10)	1.6
Materials (11)	1.5
Environmental and Ecological (7)	1.4
Industrial (15)	1.1
Biomedical (17)	1.0
Agricultural (4)	1.0

Figure 4 shows the respondents relationships with engineers, disaggregated by gender. Overall, 67% of male engineering students and 76% of female engineering students reported having a family member or close friend who was an engineer, suggesting that the intergenerational engineering narrative is important for both women and men.

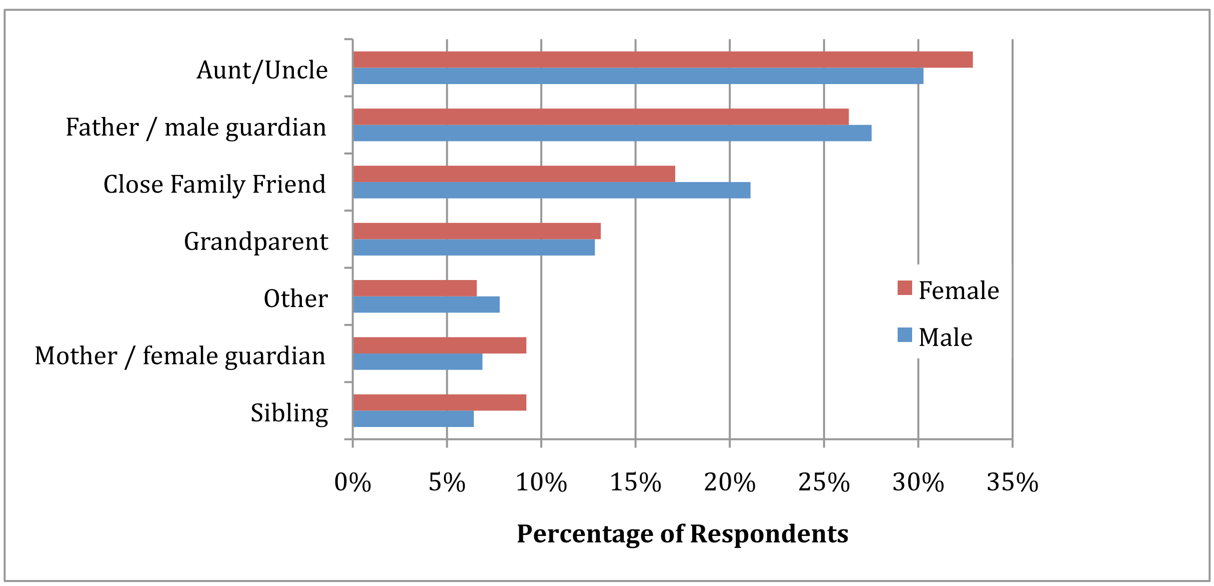

Figure 4: Respondents relationships to engineers by gender

Conclusions

The results of this paper show that there is both significant exposure to pre-college engineering activities among first-year engineering students, and significant variation in the types of activities and level of participation. In the future, we will begin to explore the relationship between participation in pre-college activities and measure of success in a university engineering program, including grades, persistence, and teamwork ability. This survey represents the first phase of a mixed-methods study of the effects of participation in pre-college engineering programs and activities on first-year students' experiences in engineering. As more students are exposed to engineering prior to matriculating into university engineering programs, the results of this research will provide valuable guidance as schools of engineering adapt to their changing first-year cohorts.

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