Female vs Male Secondary Students: Comparing and Contrasting Perceptions of Engineering

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Professor Bazylak brings his engineering, education, and design experience to his role at the University of Toronto. His primary role is coordinating and teaching an award winning first year design and communications course (Engineering Strategies and Practice). As well he conducts action-based research into improving the learning experience of undergraduate engineering students and increasing diversity in the profession, particularly women and Aboriginals (Native Americans).

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Female vs Male Secondary Students: Comparing and Contrasting Perceptions of the Engineering Skill Set

Introduction

The long-standing underrepresentation of females in engineering, both in Canada and the United States [1-3], is worrying because systemic issues may be the cause of an untapped talent pool. Furthermore, this professional underrepresentation is likely to continue since females are also underrepresented in engineering education programs [4, 5]. Figure 1 illustrates the percentage of females in Canadian undergraduate engineering disciplines, and while Biosystems is composed of a female enrolment of over 40%, most disciplines have a significantly lower percentage of female enrolment. Figure 2 illustrates the percentage of American bachelor's engineering degrees that are awarded to females, and the trend is similar in Canada (See Figure 1). Even worse, after decades of programs focusing on increasing female enrollment, we are seeing a decrease in female enrollment in Canada [4] and stagnated growth in the United States [5].

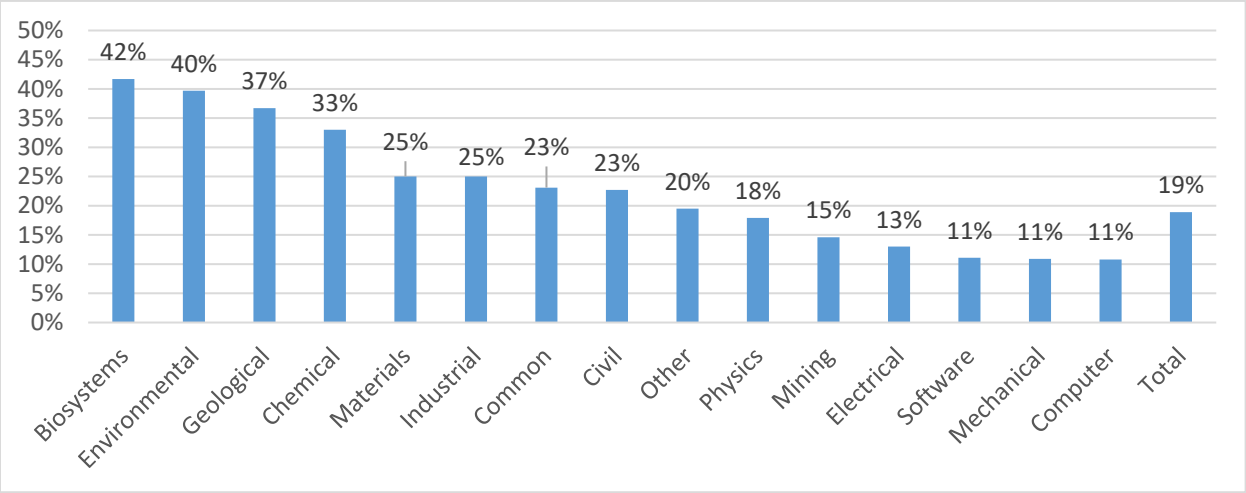

Figure 1: Canadian undergraduate enrollment of female students by discipline (2013) [4].

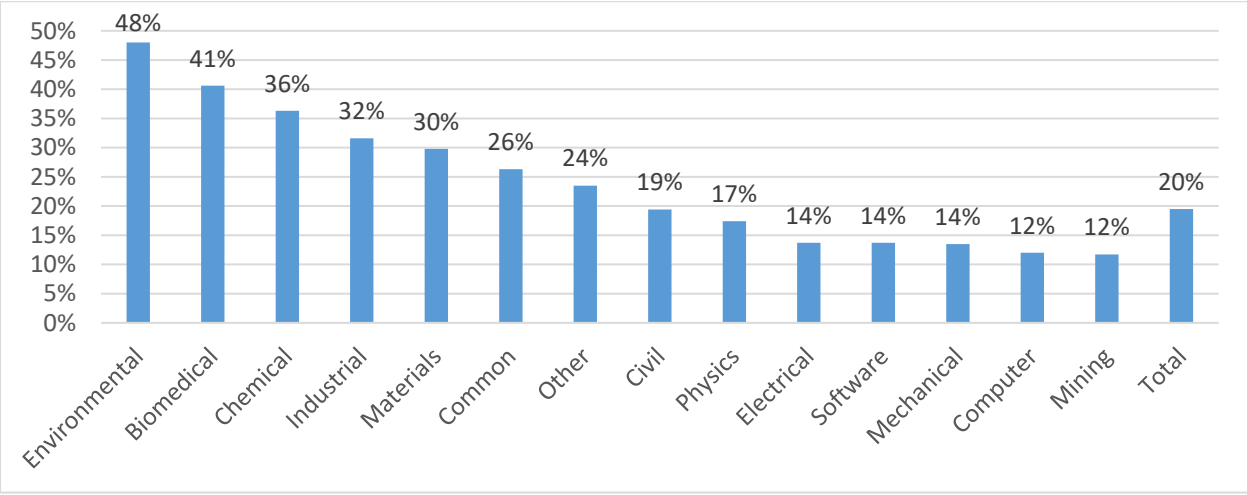

Figure 2: % of American bachelor's degrees awarded to females by discipline (2013-14) [5].

The literature points to many potential reasons for underrepresentation including differences between females and males in life goal preferences, learning styles, and even preferred working environment. For example, the literature contains theories that females seek to make social impacts, opportunities for which are not apparent to them in engineering [6]; females prefer social challenges to technical ones [7]; male dominated professions like engineering are unwelcoming to females [8]; engineering coursework is designed for a male learning style [9]; engineering is a masculine profession [10]; engineering companies have poor work-life balance policies [11]; workplace discrimination exists [12]; there is a lack of understanding of the profession [11]; perception of engineering as primarily construction work, outdoor work, working in a cubicle, and interacting with computers and machines, rather than people [11].

In particular, some reasons provided in the literature paint a highly gendered classification of talent/capabilities: females are less skilled in science and math, which diminishes female confidence (stereotype threat) [13-15]; females have an inborn disposition for 'caring' or 'humanities' jobs [16], and female secondary students have lower self-efficacy in STEM subjects and lower interest in engineering [17].

The underrepresentation of females in both Canadian and American programs is evident in Figures 1 and 2, but another interesting and yet-to-be-understood phenomenon is the heterogeneous distribution of female enrolment by program. If we understood the causes for the relatively high female enrolment in disciplines such as Chemical Engineering, then we might be able to develop strategies for increasing female enrolment in other engineering disciplines.

Within this multi-stage research project, we use survey research methods to better understand the reasons for this underrepresentation. We hypothesize that one reason for the underrepresentation is the existence among secondary students of gender-specific perceptions of: 1) the engineering profession and engineering education programs; 2) the differences between the engineering disciplines; 3) the skill set of the typical engineer; and, finally, 4) a student's own skill set in comparison to the typical engineering skill set.

In the first stage of our multistage project, we developed and presented a survey tool that: a) used inclusive language (especially around gender), b) minimized the bias in the survey language, and c) was validated [18]. For the full details of the steps taken to design and validate the survey, the reader is referred to our previous paper [18]. A brief overview is provided here for reader convenience. The survey tool was used to evaluate our hypothesis that there are three broad decision factors used by secondary students when considering whether to study engineering. These decision factors are: Perceptions – of the profession and the undergraduate programs, Achievement – to meet programs' entrance requirements, and Confidence – self-perception of qualifications and traits (See Table 1). Our first research question was used to determine the level of importance that secondary students placed on each of these decision factors.

Research Question 1: To what degree, if any at all, did these factors shape secondary students' decisions to apply to undergraduate engineering programs?

Table 1: Decision Factors in Whether to Study Engineering

Decision Factors	
Perceptions	• of Undergraduate Engineering Programs • of the Engineering Profession • of different engineering disciplines • of what skills are central to engineering
Achievement	• meet programs' entrance requirements in mathematics, science and English
Confidence	• self-perception of sufficient mathematics, science and English skills

The second research question was used to determine whether a secondary student's consideration of these decision factors was modified (influenced) by gender.

Research Question 2: How are these factors affected by Gender?

The third research question was used to determine if a secondary student's exposure to engineering or to engineers also modifies (influences) how they consider these decision factors. We also noted that the student's exposure to engineering or to engineers would also likely be modified by gender (see Figure 3).

Research Question 3: How are these factors affected by Exposure (to engineers/engineering)?

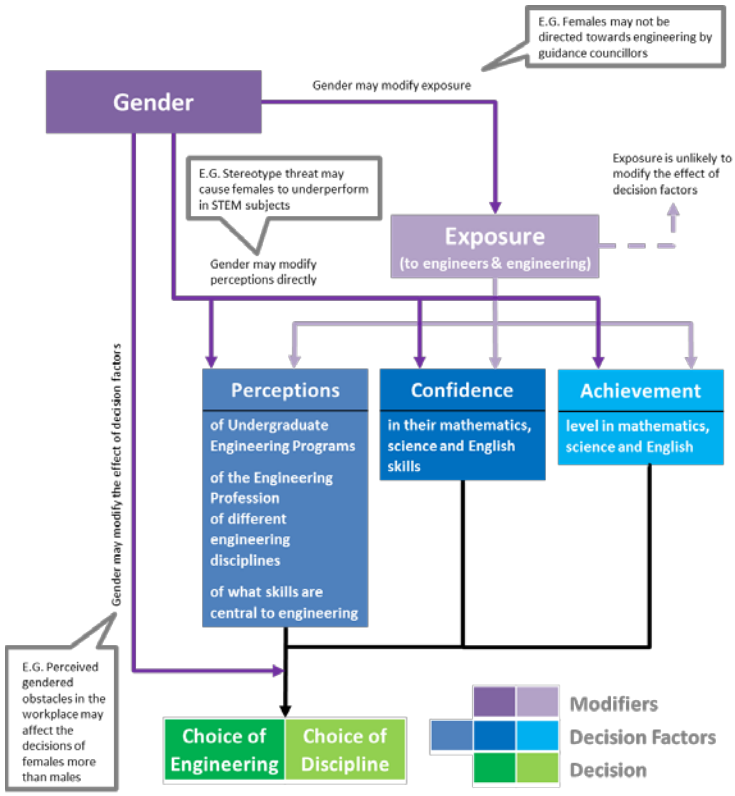

Figure 3: Model for designing the survey to measure decision factors for studying engineering.

Survey

We developed a survey to measure three categories of decision factors, Perceptions, Confidence, and Achievement (see Figure 3 and Table 1). The questions about student perceptions of the engineering skill set are used to jointly measure each student's self-understanding of engineering, as well as measure their self-confidence in their qualifications to be an engineer. The questions about student perceptions of the engineering profession were designed to explore and measure the students' understanding of the engineering profession along lines such as: masculine/feminine, low/high status, etc. The questions about the importance of decision factors gave us a better understanding of how secondary students rank the importance of various decision factors, and this understanding is vital for equipping engineering outreach programs to develop targeted recruitment materials and events to address the underrepresentation of females in engineering. This work, the second stage of this study, centres around the analysis of students' perception of the engineering skill set, their own skill set, and how these perceptions are modified by gender.

Student Perceptions: Engineering Skill Set versus Own Skill Set

After a careful literature review of existing personality and character trait tools [18-27], and failing to find an effective description of the character traits of an engineer, we took a new approach. Engineers Canada publishes a list of attributes all engineers graduates from accredited engineering programs must possess [28]. These are similar to the Student Outcomes published by ABET [29]. We used these 12 graduate attributes to derive 13 skill descriptors written in layman's terms (See Table 2).

In the survey students were asked to rate, on a scale of Exceptional – Average - Below Average, how they perceived that a typical engineer would score in these skills. Later in the survey, separated by unrelated questions, students were asked to rate their own skills on the same scale.

Table 2: Engineers Canada Graduate Outcomes and the Derived Survey Skills

Graduate Outcomes	**Survey Skill**
A knowledge base for engineering	Good with Technology
Problem analysis	Problem Solver
Investigation	Curious
Design	Likes to Make Things
Use of engineering tools	-
Individual and team work	Leadership Team Player
Communication skills	Well Spoken[1]

Professionalism	Respected
Impact of engineering on society and the environment	Socially Conscious Environmentally Conscious
Ethics and equity	Honest
Economics and project management	Organized
Life-long learning	Likes to Learn

Participants and Sampling

The survey population was a convenience sample of 50 grade 12 enrolled in two different advanced placement physics classes in a local private secondary school. 20% of the survey population identified as female. Human subjects research approval was obtained through the university ethics board. The private standing of the school was advantageous as it allowed for human subjects research approval at the school level without a long consultation process with a central school board. As most of the participants were minors the letter of consent obtained both the participants and their parents signatures. A limitation of this convenience sample was that it was not representative of the general population and therefore cannot generalized. This limits the results of this study to descriptive statistics with the goal of improving the tool and methodology for future, larger, administrations of the survey.

Data Collection

After an in-classroom presentation by two of the authors on an unrelated engineering topic, paper surveys were sent home with the survey population. The presentation and survey distribution took place late in the fall term (early December) as it was a quieter time of the school year when the participants' teacher could allocate two class periods to this activity. Two weeks later the 27 paper surveys were collected from the participants' teacher for a response rate of over 50%. Upon confirmation that both the participant and the participants' parents had signed the letter of consent, the letter was removed from the responses to anonymize the data.

Data Analysis

Despite underrepresentation of females in the survey population, over 50% of the participants identified as female. This was ideal for studying gendered perceptions, but may reflect some gendered perceptions of the importance of this area of research.

In this work two questions of the survey will be analysed, those where students were asked to rate the skill set of a typical engineer, and then rate themselves in those same skills. The 13 skills evaluated are found in Table 2. Of the 27 respondents two were removed as they had not completed both questions, leaving 13 male and 12 female respondents. For each of these 13

skills the male and female responses were separated into perceptions of the *Engineer's Skill Set* and *Own Skill Set.* Details of five of these skills are found below in Figures 4 through 8. The remaining data will be included in a future publication.

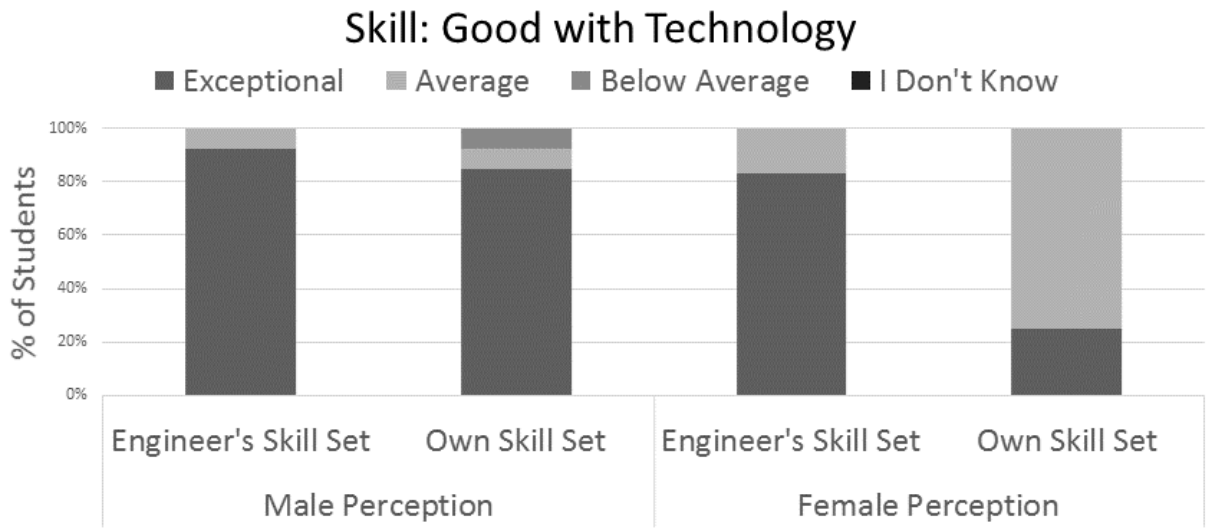

Figure 4: Perception of engineering and self-proficiency with technology by gender

Engineering Skill Comparison: Both male and female students perceive engineers to have *Exceptional* proficiency with technology.

Own Skill Comparison: There is an indication that female students perceive their technical proficiency to be *Average*, significantly lower than their expectations of the required skill set to be an engineer. Male students seemed to perceive themselves to be *Exceptional* with technology, matching with their expectations of the engineering skill set.

Results were similar for the Problem Solver skill.

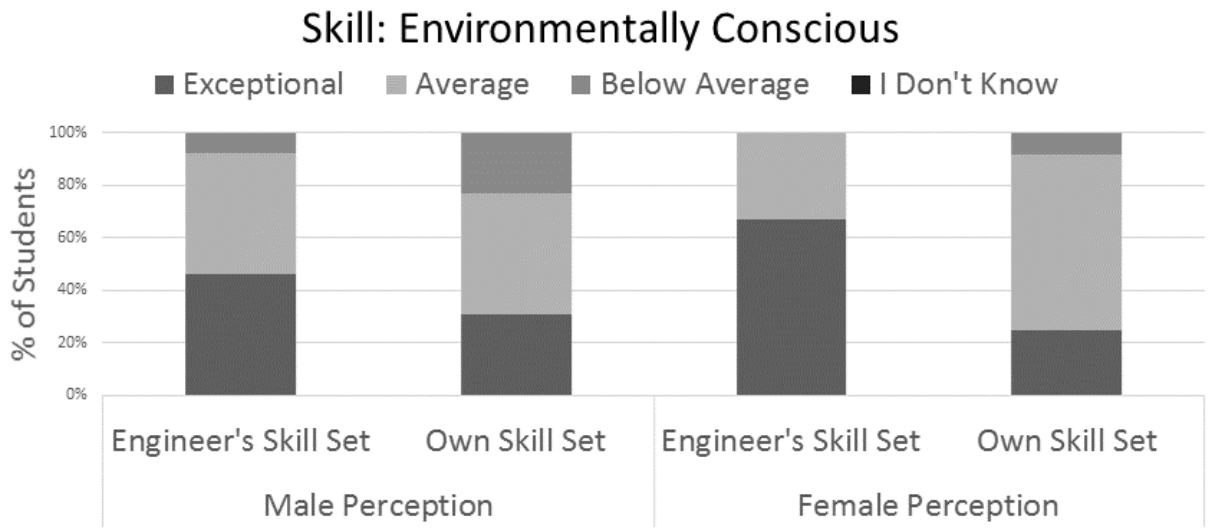

Figure 5: Perception of engineering and self proficiency in problem solving by gender

Engineering Skill Comparison: Female students seemed more likely to identify engineers as being environmentally conscious, with a strong majority going as far as saying engineers are *Exceptionally* environmentally conscious. Male students were slightly less likely to identify environmentally consciousness as an engineering skill.

Own Skill Comparison: Contrary to well believed stereotypes of female students there was no indication of a greater level of environmental consciousness. In fact, male students seemed more likely to identify themselves as *Exceptionally* conscious of the environment.

Results were similar for the Socially Conscious skill, including countering the gender stereotype that female are more socially conscious.

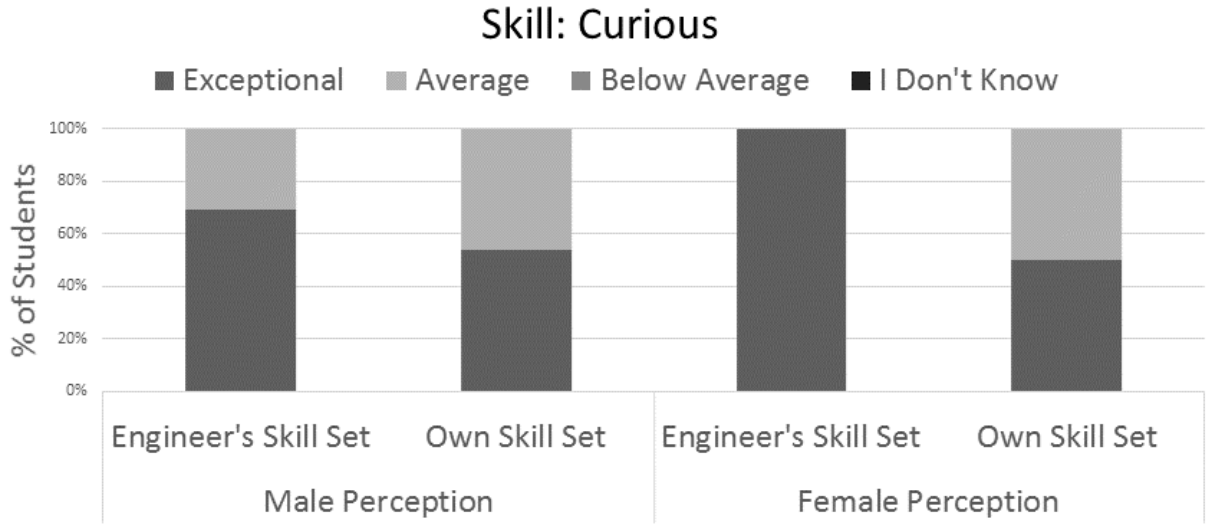

Figure 6: Perception of engineering and self proficiency in curious by gender

Engineering Skill Comparison: Male students seemed unsure whether curiosity was an engineering skill set. A slight majority thought engineers were *Exceptionally* curious, but nearly as many felt that engineers had *Average* levels of curiosity. Female students seemed clear in their belief that engineers are *Exceptionally* curious.

Own Skill Comparison: Both female and male students showed bimodal results regarding their level of curiosity. Half identified as *Exceptionally* curious and half identified as *Average*. Despite rating their own levels of curiosity similarly, the results seem to indicate a disadvantage for female students given their perception of engineering requiring high levels of curiosity.

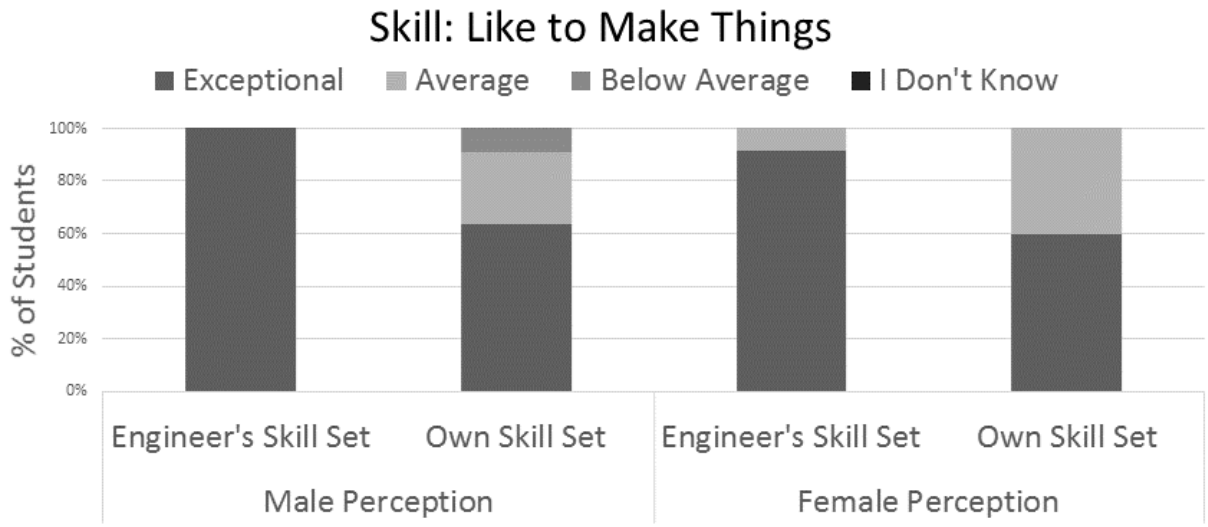

Figure 7: Perception of engineering and self proficiency in hands on skills by gender

Engineering Skill Comparison: Both male and female students perceive engineers to have Exceptional hands on skills.

Own Skill Comparison: Both female and male students agreed in their bimodal responds to this question. Half of the students identifying as having *Exceptional* hands on skills and the other half *Average* hands on skills.

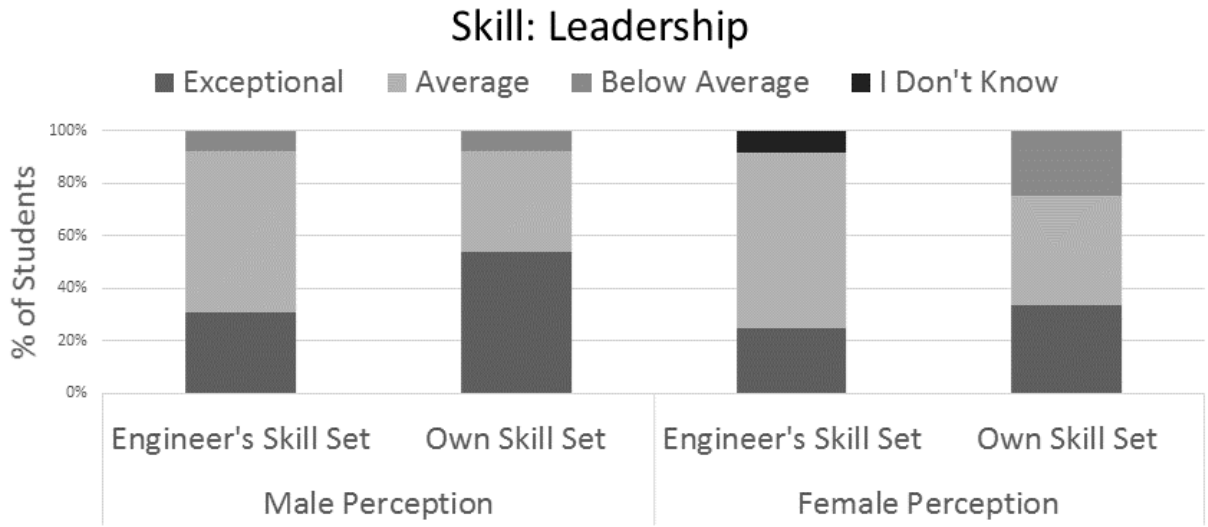

Figure 8: Perception of engineering and self proficiency in Leadership skills by gender

Engineering Skill Comparison: Female and male students seemed consistent in their perception of engineers as *Average* leaders. A small minority perceived engineers to be *Exceptional* leaders.

Own Skill Comparison: The majority of female students identified their own leadership abilities as *Average* or *Below Average*. Male students seemed more split with half identifying as *Exceptional* leaders and the others *Average* or below.

Results were similar for the Well Spoken and Respected skills.

Future work is underway to increase the survey population in order to allow for statistical analysis and confirmation of the above identified indicators. In preparation for this future work we devised a method of quantifying results to these questions. We aggregated the Exceptional – Average – Below Average responses within each gender perception into a single value for each skill. A value was assigned to each type of response (*Exceptional* = 1; *Average* = 0; *Below Average* = -1; The "I Don't Know" responses were not considered here), and the following relationship was used to measure the Engineering Skill Match Factor.

$$\begin{aligned} &Engineering\ Skill\ Match\ Factor \\ &\quad = (\#\ Exceptional\ Responses \times +1) + (\#\ Average\ Responses \times 0) \\ &\quad + (\#\ Below\ Average\ Responses \times -1) \end{aligned}$$

Equation 1: Engineering Skill Match Factor

This aggregated parameter serves as an indicator of how a gender perceives its own skills when compared against the perceived skill set of an engineer. A positive value indicates the gender perceives itself as more qualified than a typical engineer. While a negative value indicates the gender perceives itself as less qualified than a typical engineer. The Engineering Skill Set Match Factor for the 13 skills surveyed are summarized in Figure 9. Given the limitations of this study due to sample size should only be used as a demonstration of this methods and will not be generalizable until a larger and more representative population is surveyed.

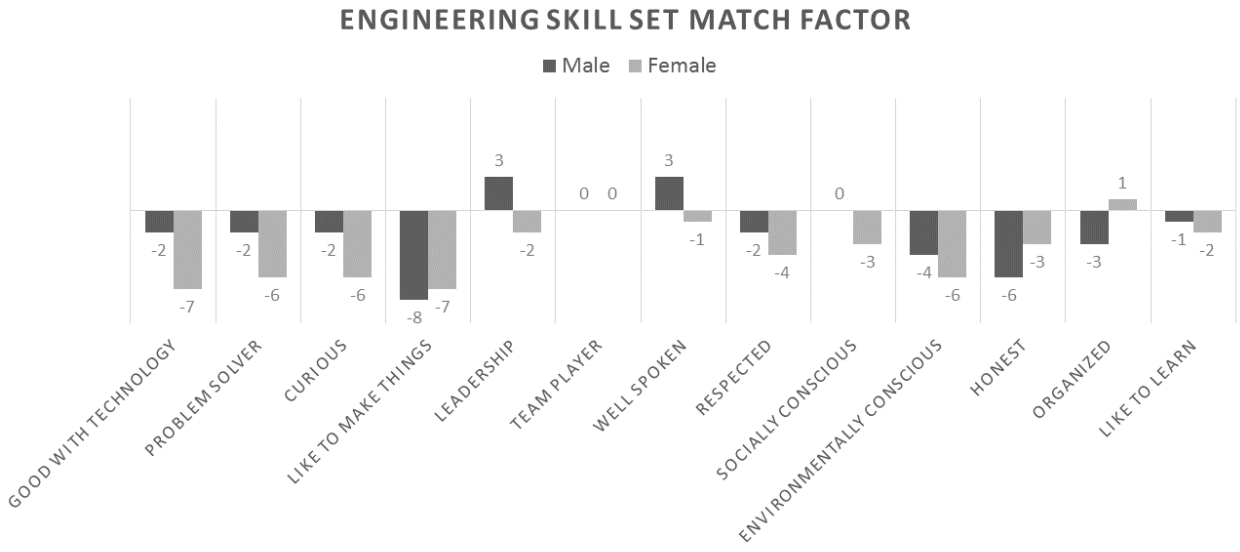

Figure 9: The Engineering Skill Set Match Factor for each of the 13 skills surveyed

Conclusions

From this first investigation with our newly developed survey tool, we identified several points of interest for future study, including indicators of reinforcement of some stereotypes and diminishment of others.

Engineering Skill Set - Gender Agreement: Both male and female students seemed agreed in their perception of the following strengths and weaknesses of a typical engineer.

- *Engineers Are Exceptional at*: Technology, Solving Problems, Making Things, and Learning.
- *Engineers Are Average at*: Teamwork and Organization
- *Engineers are Below Average at*: Leadership and Communication

Engineering Skill Set - Gender Disagreement: There seemed to be indications of differences in male and female students' perceptions the strengths and weakness of a typical engineer.

- Female students had a higher perception of engineers believing them to *Exceptional* Curious
- Female students had a higher perception of engineers believing them to be at least *Average* at: Respectability, Socially and Environmentally Consciousness, and Honesty
- Male students' perceptions of engineers was never greater than their female counterparts.

Female Perceptions of Deficiency: Female students seemed to perceive themselves as deficient in skills which they defined as critical to the engineering skill set. Including: Good with Technology, Problem Solving, Curiosity, Like to Make Things, Environmentally Conscious,

Female Perceptions of Strength: Female students seemed to perceive themselves as stronger than a typical engineer only for skills that they perceived as not core to typical engineer's skill set, such as Leadership, Teamwork, and Organization.

Male Perceptions of Deficiency: Male students seemed to perceive themselves as having minor deficiency in a few skills, none of which they identified a highly valuable for a typical engineer. Including: Curiosity, Making Things, Honesty, and Organization.

Male Perceptions of Strengths: Male students seemed to perceive themselves as being stronger than the typical engineer in several skills, including: Leadership, Communication, and Socially Conscious.

In our small sample there is a clear indication that perceptions of the engineering skill set and a student's own skill set are modified by gender. These differences all seem to disadvantage a female student who is interested in the engineering profession. Once this survey is administered to a larger more representative population these preliminary indicators can be confirmed or refuted. If confirmed then these new insights into gendered perceptions of engineering can be used to provide new pathways for improved recruitment approaches for female and male students interested in engineering.

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