AC 2010-1667: AN EXAMINATION OF INDUSTRY'S DESIRED TRAITS FOR ENGINEERING GRADUATES AND GENDER DIFFERENCES

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An Examination of Industry's Desired Traits for Engineering Graduates and Gender Differences

Abstract

The National Academy of Engineering, among other organizations, regards hands-on ability as an important trait of engineering graduates. However, it is unclear how faculty, students, and industry prioritize hands-on ability relative to other desirable traits. Surveys were given to industrial representatives, faculty, and students asking them to rate hands-on ability among eight other traits. Analysis found that hands-on ability ranked third. Understanding the importance of hands-on ability would better allow engineering curricula to reflect its prioritization. Hands-on ability also has gender associations. Better understanding how industry views this could allow curriculum to prepare its students to meet this obstacle. It would also allow academia to realize the gender association and address it within the institution. These changes could allow better engineering experiences for female engineers as well as males.

Introduction

An important consideration for curriculum change and improvement is to identify the desirable attributes of a graduating engineer. While calling for significant reforms in engineering education, the National Academy of Engineering (NAE) recommends the Engineer of 2020 have: strong analytical skills; practical ingenuity; creativity; communication; business and management knowledge; leadership; high ethical standards and professionalism; dynamism, agility, resilience, and flexibility; and the habit of lifelong learning[1]. Other organizations have developed similar lists. For example, in a study pertaining to computer science majors, employers and teaching staff rated the following attributes as highly important: analysis skills, application of knowledge, communication, capacity to learn, information management skills, team competency, ability to work in interdisciplinary teams, ability to work autonomously, and concern for quality as highly important[2]. The European higher education places emphasis on employability, learner-oriented learning outcomes, and subject-specific and generic competences[3, 4]. Employability is an overarching trait that is deemed important in graduating engineers[5, 6].

Besides academies like the National Academy of Engineering, surveys of engineering industrial representatives and graduates have determined hands-on ability to be important. Duy Nguyen surveyed nearly a hundred individuals from industry and asked them to rate (out of a hundred) the generic qualities and attributes necessary for the development of a professional engineer. The highest ranking category, with a value of 92.30, included hands-on skills[7]. Although engineers today are not typically hired to tear apart engines, they are still expected to have the hands-on skills. There seems to be a connection between engineering and the ability to perform hands-on tasks. In support of this, when 420 industrial representatives were surveyed in 1999, they identified the ability to connect the theoretical and practical as the highest engineering trait[8]. McIlwee and Robinson surveyed over four hundred graduates who graduated between 1976 and 1985 in southern California. The surveys revealed that hands-on ability is important in the workplace. Whether the graduate uses hands-on ability on the job or not, "they need to be able to present themselves as someone who is capable of doing so[9]."

Men and women are often viewed differently in the engineering industry, particularly in the area of hands-on ability. For example, during their interviews McIlwee and Robinson recorded instances where women were at a disadvantage in the workplace. One women was assigned to a project "for about two years with the same engineers (who were male) …[and he said] 'Oh, you're not just another dumb blond.' It was like, 'well, finally…' But I guess it just took so long. It was so hard to get to that point, and [his comment] just cemented the fact that this man was thinking this for the last two years[9]." Another woman, just starting an engineering job, recounted an experience in which an experienced male engineer asked her to hand him a particular tool. She did not know what he was talking about: "He just looked at me like, 'oh my god, here we go.' On my first day!... I wanted to quit[9]." Both women felt that their gender imposed judgment on their skills in the workplace.

When the mechanical engineering curriculum at our institution was revised in 2000, one of the goals was to give students more hands-on experiences. The practical-theoretical dimension of engineering education is, by no means, the only one–it does not adequately capture curricular elements addressing communication skills and teamwork, for example. Nevertheless, the balance between the practical and theoretical remains a focal point in the endeavor to educate agile engineers. Even as engineering work becomes increasingly sophisticated, practical ability and intuition about physical phenomenon remain important.

As a step before embarking on more improvement efforts at our institution, we wished to confirm the importance of hands-on ability with engineering employers. We believe that hands-on ability has a role to play both in ensuring that engineering graduates have the necessary knowledge and skills for engineering work in the 21st century, and in improving opportunities and experiences for females in engineering. We developed and administered a survey that asked employers to rate the importance of hands-on ability along with other desirable engineering traits.

Analysis of results from survey responses prompted additional questions about the role of gender in the hiring process evaluation of engineering grads. Since gendering of professional identities has been realized in engineering[10], a second version of the survey was developed to examine whether differences in job candidate gender affect the rating of desirable engineering attributes. Other research has shown that we do not view others simply as people[11]. Instead we see them as males or females. When gender schemas are invoked, they work to a disadvantage to women by directing and skewing our perception[11]. In the engineering workplace, which has traditional male traits and is male dominated, women often attempt to assimilate by disqualifying their femininity and by matching the male styles of behavior[12].

Survey Version 1

In the first survey, we asked respondents to rate the relative importance of various attributes (including hands-on ability) for new engineering hires. Our list of nine attributes looks similar to those compiled by various engineering organizations, including the NAE. The surveys were administered to exhibitors at an engineering conference in October 2008 and to recruiters at an on-campus career fair in February 2009. Respondents rated the nine traits on a scale of 1, low importance, to 5, high importance. A definition was provided to clarify the meaning of each trait name. Table 1 lists the nine traits and their definitions.

Table 1: Trait definitions given in first version of survey

Student Trait	Definition
Academic ability	The student has a high college grade point average
Communication skill	The student writes well, is comfortable making oral presentations, and is able to communicate effectively with people that have different job functions
Leadership ability	The student has held leadership positions in student organizations or on project teams
Hands-on ability	The student has tinkered with machinery or electronics as a hobby or job, or grew up in an environment where these skills were required (such as a farm).
Teaming ability	The student has done many team projects and works well with others
Prior work experience	The student has engineering intern or co-op experience
Multicultural experience	The student speaks a foreign language, has lived or worked in another country, or has worked with culturally different people
Creative ability	The student "thinks outside the box", has worked on inventions, or is involved in artistic pursuits
Ethical reasoning	The student had a course in professional ethics and/or demonstrates an ability to see technological solutions in a broader context.

In April 2009, faculty and students at our institution completed a similar survey. The survey differed from the first survey because it provided slightly more details in the instructions. It asked the respondent to rate the value of the attributes listed above for an engineering graduate entering industry. The original survey asks the respondents to rate the traits. The directions were clarified to allow the undergraduates to better understand the context of the survey. The clarification could slightly alter the responses between the two surveys; however, since the purpose of the survey is to understand the relative importance of hands-on ability, the results from both surveys were included. The survey asked which engineering major the student or faculty member primarily instruct or major in. The faculty responses were gathered at a faculty meeting using paper surveys. The student responses were gathered using an online survey tool. Student participation was encouraged by entering respondents in a drawing for gift cards.

For the first version of the survey, we collected 54 surveys from industry representatives, 29 surveys from mechanical engineering faculty members, 62 surveys from freshmen engineering students, and 95 surveys from mechanical and electrical engineering seniors. Figure 1 shows the means and 95% confidence intervals for the responses in each group.

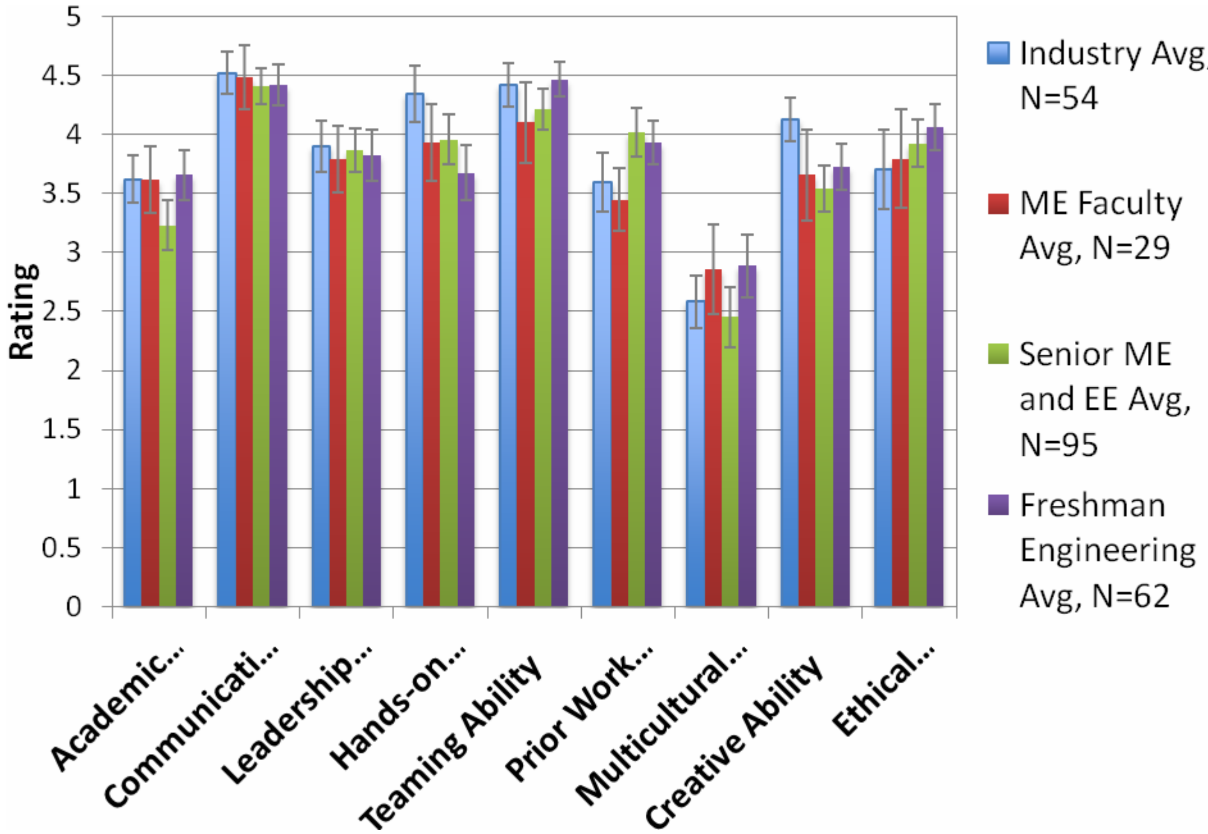

Figure 1: Average ratings for the nine traits by response group with a 95% confidence interval

In general, the results show good agreement between response groups for the nine traits. The highest rating categories overall were communication and teaming ability while the lowest was multicultural experience. Hands-on ability rated third highest. Industry rated hands-on ability and creative ability higher than the other groups. Students rated ethical reasoning and prior work experience higher than industry and faculty. Ethical reasoning along with multicultural experience had the largest confidence interval. The results are discussed in more detail in the previous paper "Determining the Importance of Hands-On Ability for Engineers[13]."

Survey Version 2

In September 2009, a new version of the survey was developed to investigate whether certain traits might have implicit associations with a particular gender. For example, is it possible that a respondent could rate hands-on ability higher when associated with a male name rather than a female name because they associate that ability with men? To test this idea, the survey was modified and administered to 83 recruiters at a career fair in September 2009. Respondents were not asked to identify the company they represented to reduce possible response pressure. Each question in the modified survey described a fictional student who was strong in one particular attribute. Table 2 shows how the attribute definitions were modified. The number of attributes was reduced from nine to seven by stating that all the students had the same academic performance and prior experience. The attributes were reduced to shorten the response time and increase the number of respondents. A question was also added to determine if the respondent was an engineer, supervisory engineer, or from human resources. A total of 39 engineers, 20 supervisory engineers, 12 human recourse representatives, and 13 others responded. The 13 others who responded wrote in a different representation including IT management, account manager, recruiter, and project engineer. Both male and female names were used in the attribute descriptions. The names were selected from the most popular baby names of 1986, the year representing the majority of students at the career fair. However, names that are commonly used for either gender were discarded. The top four male and top four female names were randomly distributed across the seven questions differently for each survey. The names used were Amanda, David, Jason, Jennifer, Jessica, Josh, Melissa, and Michael. When tallying the surveys, separate attribute averages were calculated for each gender.

Table 2: Trait definitions given in second version of survey

Trait	**Fictional student definition**
Communication skill	[Student name] is a strong writer who gives excellent oral presentations. [She/he] is able to communicate well with people from different departments and backgrounds.
Leadership ability	[Student name] has held many leadership positions, including undergraduate student council president. [She/he] also played a crucial role as team lead on [her/his] senior project.
Hands-on ability	[Student name] has tinkered with both machinery and electronics as a hobby since [she/he] was seven on her family's farm. [She/he] eventually put [her/his] skills to use in the machine shop on campus.
Teaming ability	[Student name] has worked on many team projects. [She/he] has a strong ability to work well with others.
Multicultural experience	[Student name] speaks German and has lived and worked in Germany. [She/he] now works in the international office on campus.
Creative ability	[Student name] has continually come up with original ideas. [She/he] has demonstrated abilities to see technological solutions in a broader context during [her/his] senior project.
Ethical reasoning	[Student name] has taken a course in professional ethics; [she/he] also has demonstrated abilities to see technological solutions in a broader context during [her/his] senior project.

The mathematical analysis used to discern a difference in gender name trait was the f-test. It was most appropriate (rather than a t-test) because data was not normally distributed. Since all the surveys were randomly distributed at the same career fair during the same time frame, it was assumed that the variances per question trait were the same. Under the null hypothesis that there is no difference among the treatment means, two estimates of the experimental variance were created. The two estimations are within-treatment mean square s_{wt}^2 and between-treatments mean square s_{bt}^2. When the observed value for s_{bt}^2 is much larger than s_{wt}^2, the added variation in s_{bt}^2 can be attributed to real differences that exist among the treatment means[14].

The F value is calculated as:

$$F_{calc} = \frac{s_{bt}^{\ 2}}{s_{wt}^{\ 2}}$$

where

$$s_{wt}^{\ 2} = \frac{\nu_f s_f^{\ 2} + \nu_m s_m^{\ 2}}{\nu_f + \nu_m}$$

$$s_{bt}^{\ 2} = \frac{n_f\left(\overline{y}_f - \overline{\overline{y}}\right)^2 + n_m\left(\overline{y}_m - \overline{\overline{y}}\right)^2}{k-1}$$

and where s_i is the sample variance of treatment *i* (*i* equals *f* or *m* for female and male, respectively), *n* is the number of samples in the *i* treatment, ν is the degrees of freedom in the *i* treatment, *k* is the number of different treatments, $\overline{y}_i$ is the average of treatment *i*, and $\overline{\overline{y}}$ is the overall average[14]. The responses were further analyzed based on the job of the respondent (engineer, supervisory engineer, and human resources) and by type of majors being recruited.

Table 3: Gender name significant traits

Significant trait	Sorted by	F-calculated value	F-table value	Female avg score	Male avg score
Communication	All categories	2.08	1.84	4.20	3.92
Leadership	All categories	3.68	1.79	4.28	3.89
Communication	Engineer job description	3.54	2.28	4.23	3.65
Multicultural	Engineer job description	3.98	2.28	2.55	1.88
Communication	Mechanical egr recruiter	2.85	1.89	4.15	3.77
Leadership	Mechanical egr recruiter	4.48	1.84	4.35	3.87
Communication	Electrical egr recruiter	1.94	1.89	4.10	3.81
Leadership	Electrical egr recruiter	3.91	1.84	4.29	3.85

Table 3 summarizes the significant findings. In order to be significant, the F-calculated value had to be greater than the F-table value. When the F-calculated value is larger than the table value, we can say that the null hypothesis is void. In this case a 95% confidence interval was used to determine the F-table value. When all surveys were examined together for gender trait average differences, two traits--communication and leadership--had significant differences. The higher average ratings for the female names suggest that women with strong communication and leadership skills stand out for employers more than males with the same skills. Male versus female names by trait were then examined by respondent job description (engineer, supervisory engineer, or human resources). For the set of surveys completed by supervisory engineers or human resources personnel, none of the traits showed a significant difference for name gender. This is likely attributed to the low numbers of surveys completed by supervisory engineers and human resource personnel: only 20 and 12, respectively. A low number of samples causes a wide confidence interval (high F-table value) which is then difficult to show significance with. The engineer job description, with 39 responses, showed two traits as being significant, communication and multicultural. The female names had higher average scores in both cases signifying that women with strong communication skills and multicultural experiences are viewed more positively than men with the same attributes.

Responses were also sorted by type of engineers the company or organization hired. We focused on companies that hire mechanical and electrical engineers. The two groups had sample sizes of 62 and 67, respectively. Both groups had similar outcomes with female names rating higher for the leadership and communication attributes.

It is interesting to note that all the significant traits were "soft" skills. In the cases where name gender was significant, the women were always rated higher on average than males. It is also worth noting that a career fair may not be an accurate representation of the engineering field. One possible reason is recruiters may be directed to focus on the recruiting of more women and minorities. For example, government agencies actively recruit females and minorities in an effort to increase representation of both in the workplace. Besides government agencies, other recruiters may focus on recruiting women. McIlwee and Robinson suggest that since the majority of graduates in engineering are male, graduating women are sometimes viewed as "tokens[9]."

Conclusion

The surveys administered to conference attendees, mechanical engineering faculty, freshmen and seniors in electrical and mechanical engineering, and both career fairs had good agreement between the examined traits. Communication skill was the highest rated trait when all surveys were averaged and was in the top two categories for each group of respondents. Multicultural experience was the lowest rated trait for each group of respondents.

The altered survey administered at the career fair in September 2009 did show gender name discrepancies, most commonly with leadership and communication traits. However, the results are preliminary and serve as a probe into future research. Somewhat unexpectedly, the survey did not show a gender difference for hands-on ability. One possible reason is that the hands-on survey question with a female name states that the woman has previous hands-on experience. Whereas an employer might assume that a male applicant has hands-on skills, female applicants have to prove they possess hands-on skills[9]. Future research could include rewording the statement to make the level of hands-on skill more ambiguous.

During McIlwee and Robinson's interviews of engineers, when respondents were asked if there was any aspect of engineering in which women were better than men, both genders agreed that it was people skills[9]. Both leadership and communication fall into the category of people skills which could explain why females were rated statistically higher in these areas. Again, if the questions were reworded to more vaguely describe the level of skill in each trait, more traits could become statistically significant according to name gender.

Future research also includes redesigning the second survey. The seven traits should be made to more equally represent levels of ability and experience. More steps to validate the survey, including respondents reading aloud the survey to check survey accuracy, will be taken. The introductory paragraph of the student background should describe more than the student's academic ability and prior experience. In the future, having respondents provide their gender could provide data for interesting analysis. Other possible future studies could include administering the same survey to engineering students, faculty, and industry in a setting other than a career fair. It would be interesting to see if the results remained consistent across a range of demographics.

Hands-on ability ranked third highest on average in the first survey and fourth highest in the second survey, amongst a list of traits that are all considered important[1]. This stresses the importance of hands-on ability in curriculum and the importance for both males and females to experience hands-on activities. Although the second survey did not show a gender name difference in the hands-on trait, this paper has outlined future research that could. Realizing different gender association would better allow for undergraduate curriculum to address this issue.

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