Perception versus Reality: Skill Perceptions of First-year Engineering Students

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This Research study is predicated on the fact that engineering students often enter the field not fully understanding the reality of the roles and responsibilities of an engineering professional. Not coincidentally, engineering is oft-cited as a major that students do not remain in. Koenig [1] found that in the STEM majors only 58% of students remain in those fields at the end of their freshman year. While there are numerous reasons for this attrition, it is likely that a part of the problem is that first–year engineering students may not have an accurate understanding of the skills necessary for a successful career in engineering. Similarly, these first year students come to the career with different motivations. The purpose of this research was to better understand the perceptions of first-year engineering students as they entered a program that was developed with a hands-on, practical focus in order to prepare students for industry after graduation. Because of the program's foundational idea being that the BS in Engineering is an "engineer in training degree" it is important to access entering student's preconceived notions of the field so that corrections can be made at the outset [2]. As this program is in its infancy and course creation is on-going, the researchers felt that it was important to better understand incoming students so that the content of their introductory course could be tailored to meet their needs and better prepare them for the reality of their coursework and a career in engineering.

Skills Perception

This work was based upon past research that looked at how skills are perceived by engineering students. In a survey of over 6100 engineering students, Besterfield-Sacre, Moreno, Shuman, and

Atman [3], examined student perceptions of their strengths and skills as they entered an engineering program. A large gender gap was found, particularly in females' initial attitudes that reflected lower confidence in their knowledge and abilities that would help them in the field. Recently, there has been a greater acknowledgment that many engineering soft skills, such as leadership and managerial functions, have been learned on the job in the past, but should instead by an explicit part of the engineering curriculum due to their importance [4].

Often students do not fully recognize the skills that they need to be successful engineers. Part of the reason for this is that engineers mostly work behind the scenes and do not generally interface with the public, thereby creating some mystery about what the work of an engineer actually entails [2]. To help counter that Davis, Beyerlein, and Davis [5] developed an engineering profile that identified the skills necessary to engineers who were successful in their field. These skills can be built into engineering assignments and assessed through grades to ensure that engineering students become "quality learners" of these necessary skills [6].

Motivation

Motivation for choosing to pursue a degree in engineering likely also factors into perceptions and, ultimately, success. In a study of Danish engineering students, male students reported greater intrinsic, financial, and social good motivation than female students for entering the field. Female students reported greater motivation from mentors than male students [7]. Motivation to complete the work within the program is an important factor as well and determining whether students are mainly motivated extrinsically or intrinsically can and should influence pedagogy and assessment [8].

Student Success and Engineering Education

Students in STEM programs have higher attrition rates than other fields, ultimately causing greater demand for workers in these fields than colleges actually graduate [9]. In analyzing successful approaches toward increasing student persistence, early research experience, active learning and STEM learning communities are three key practices. In addition to these approaches, there is some indication that personality and learning preferences should be an additional consideration. For example, the United States Coast Guard Academy employed pedagogy that was better tailored to student personality types as determined by a Myers-Briggs Type Indicator to better engage and increase success for students in a civil engineering program [10].

Methods

In the first week of the semester, students in the Fall 2016 and 2017 Introduction to Engineering class were given a short paper survey about the skills they thought engineers needed and their motivations for enrolling in an engineering program, along with basic demographic questions.

Population/Sampling

In the second year of the engineering program at a private university in the southwest United States, 75 students were sampled in the initial introductory course. In the following fall (2017) there were roughly 300 students enrolled in the program and intro course with a majority being sampled. Of that population, 324 participants completed the survey in total.

Data Collection Procedures

Surveys were created by the researchers to include the skills most needed within the industry, as determined by a faculty member who was key in creating the institutions' engineering program and based upon her prior industry experience and aligning with ABET's criteria for student outcomes in engineering programs [11]. Surveys were administered during the first week of the introductory engineering course to enrolled first-year undergraduates in the beginning of the fall 2016 and 2017 semesters. This data was used in aggregate. No personal identifying information was asked for on the survey and surveys took roughly 10 minutes for participants to complete.

Data Analysis Procedures

Survey results were entered into SPSS where participant responses were simply converted to numerical values for ease of calculation with no identifying information. The lower the numerical value, the higher the perceived importance by the participants. Basic descriptive statistics and a Krusakal-Wallis ranked order test were completed on the data. The descriptive statistics include mean and standard deviation as well as histograms to determine the general distribution. The Kruskal-Wallis test is a nonparametric method for testing two or more independent samples. As this is ranked data, the Krusakal-Wallis test was deemed appropriate by the researchers.

Results

The students' survey data was analyzed for basic descriptive statistics of mean and standard deviation. Table 1 show that on average the skills perceived to be of the highest importance by participants are math skills and critical thinking. The lower the score, the higher the importance.

Critical thinking yielded a mean of 1.28 and math skills a mean of 1.34. The skill with the lowest perceived importance is writing with a mean of 2.28.

Table 1

Perceived Importance of Skills

Skill	*n*	Mean	SD
Math	324	1.34	.855
Verbal Communication	324	1.66	.885
Writing	323	2.28	.951
Team Work	324	1.42	1.015
Critical Thinking	324	1.28	.994
Organization	324	1.58	1.039
Creativity	324	1.42	.867

Following the descriptive statistics analysis, the Kruskal-Wallis Test was completed on the ranking of the skills to determine if there is a statistically significant difference in the perceived importance. SPSS was used to complete the test. Table 2 shows the mean rank for each of the skills which was used to determine the test statistic.

Table 2

Krusakal-Wallis Test Ranking of Skills

	Question	*n*	Mean Rank
Rank	Math Skills	324	804.25
	Verbal Communication	324	1054.22
	Writing	324	1460.50
	Team Work	322	1406.73
	Critical Thinking	324	848.23
	Organization	324	738.53
	Creativity	324	981.21

A Kruskal-Wallis H test showed that there was a statistically significant difference in the importance of the different skills, $\chi^2(6) = 410.501, p < 0.0001$, with a mean rank of 804.25 for math skills, 1054.22 for verbal communication, 1460.5 for writing skills, 1406.73 for team work, 848.23 for critical thinking, 738.53 for organization, and 981.21 for creativity.

A Friedman test did not find a statistically significant relationship between having a family member in the engineering filed and the perceived importance of the skills.

Discussion

Ultimately students ranked math and critical thinking skills to be the most important in their future profession, which is not all that surprising. These findings were also in line with prior ABET results. According to ABET's list of eleven student outcomes in an engineering program, two of these skills are rated quite low on student perceptions: "an ability to function on multidisciplinary teams" and "an ability to communicate effectively" [11]. Teamwork, verbal communication, and writing were at the bottom of student rankings, consistent with ABET's results.

Perhaps also unsurprisingly, students viewed writing skills to be the least important, supporting Guilford's [12] assertion that though an engineer may spend a large proportion of each day writing, engineering students tend to not see writing skills as a need in engineering education. This perception seems to be one that most needs addressing within the curriculum and was part of the prompting to create a course for writing in engineering that students would take, in

addition to their mandatory general education composition courses, thereby reinforcing the importance of written communication within the profession.

Knowing which skills are most valued by students allows faculty to determine which lessons need more explanation than others. Students value lessons on certain skills over others and so they are likely to innately see the importance of lessons and labs centered on math or critical thinking. The converse is also true and has large implications for how faculty present materials. If students do not view writing or team work as skills important to their future as engineers, they will not be as engaged and will be less likely to buy into those aspects of a class. Students will perform better on lessons with a focus on these skills so including explanation of the importance or extra time with the other skills will likely improve student outcomes.

Aside from just engineering skills, as Utschig, Newton, and Bryan [6] point out in their work establishing a profile for engineers, the skills surveyed here are key to success in professions beyond just STEM. Because a large number of freshmen engineering students are likely to transfer into other majors due to the rigor of the programs, building in awareness and first-year focus on these skills helps both engineering students and those that move into other disciplines.

Another consideration that these results might point toward is that student skill perceptions surveyed here are actually more closely aligned to the student's own learning preferences rather than their understanding of the profession. This would support the Coast Guard Naval Academy prescription to have more active learning and Myers-Briggs Type Indicator assessments to better meet each student's learning preferences [10].

It was surprising to not see a correlation between the ranking of skills and the reporting of having a close relative in the field. As the National Academy of Engineering asserts, engineering is not a very public facing discipline for the most part [2] and so while it is understandable that the majority of student who select engineering as a major may not fully understand all that the profession entails, the researchers thought that having a relationship with an engineer might be a mitigating factor in perceptions of the profession.

Additionally, these results differed from the findings in Besterfield-Sacre, Moreno, Shuman, & Atman [3] that skill perceptions differed by gender. The current research did not reveal any such disparity in how females and males view engineering skills.

Limitations

This project was initiated in the first and second year of new programs. As such, there is not exit survey data for these cohorts, although that would likely make for interesting analysis. It would have been nice to have longitudinal data to see in what ways did the program change or solidify student perceptions of disciplinary skills. Do upperclassman have a different view of skills than entry level engineering students. Do first-year introductory classes help to move the needle in how the skills are viewed?

Future Research

A more in-depth analysis that looks at outcomes and how they correlate to skill perceptions would be an interesting and necessary way to follow up on this study. In particular, focus groups

with students would likely help provide insights and perceptions beyond just survey data and might even allow us to better understand the root of the perceptions in a field that is not often viewed by outsiders. Additional research to incorporate motivational factors into the analysis is also desirable for greater understanding of why students enter the field. Linking skill perceptions and motivation to persistence and program success (as measured by GPA) would also provide greater insight into if and how final outcomes are impacted by incoming student expectations.

References

[1] K. Koenig, M. Schen, M. Edwards, and L. Bao, "Addressing STEM retention through a scientific thought and methods course." *Journal of College Science Teaching*, vol. 41, no. 4, p. 23, 2012.

[2] National Academy of Engineering, "*Educating the engineer of 2020: Adapting engineering education to the new century."* Washington, DC: The National Academies Press, 2005. Available: https://doi.org/10.17226/11338.

[3] M. Besterfield-Sacre, M. Moreno, L. J. Shuman, and C. J., "Gender and ethnicity differences in freshmen engineering student attitudes: A cross-institutional study." *Journal of engineering Education*, vol. 90, no. 4, pp. 477-489, 2001.

[4] S. Kumar and J. K. Hsiao, "Engineers learn 'soft skills the hard way': Planting a seed of leadership in engineering classes." *Leadership and Management in Engineering*, vol. 7, no. 1, pp. 18-23, 2007.

[5] D. C. Davis, S. W. Beyerlein, and I. T. Davis, "Development and use of an engineer profile." *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition*, June 2005.

[6] T. T. Utschig, S. M. Newton, and J. S. Bryan, J. S., "Measuring skills across the profile of a quality learner and of a quality engineer." *International Journal of Process Education*, vol. 4, pp. 3-12, 2012.

[7] A. Kolmos, N. Mehlgaard, S. Haase, and J. E. Holgaard, J. E., "Motivational factors, gender and engineering education." *European Journal of Engineering Education*, vol. 38, no. 3, pp. 340-358, 2013. Available: http://dx.doi.org/10.1080/03043797.2013.794198

[8] N. Savage, R. Birch, and E. Noussi, “Motivation of engineering students in higher education,” *Engineering Education*, vol. 6, no. 2, pp.39-46, 2011.

[9] M. J. Graham, J. Frederick, A. Byars-Winston, A. B. Hunter, and J. Handelsman, “Increasing persistence of college students in STEM.,” *Science*, vol. 341, no. 6153, pp.1455-1456, 2013.

[10] C. Fleischmann, E. Nakagawa, and T. Kelley, “Redesigning the student learning approach through personality types and pedagogies: A case study in an undergraduate engineering course,” *Universal Journal of Educational Research,* vol. 4, no. 2, pp. 426-431, 2016. doi:10.13189/ujer.2016.040217

[11] ABET. “Criteria for evaluating engineering programs, 2018-19.” Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/#GC1

[12] W. H. Guilford, “Teaching peer review and the process of scientific writing,” *Advances in Physiology Education,* vol. 25, no. 3, pp. 167-175, 2011.

Appendix A

Rate how important the following skills are to your future career in engineering:

	Very Important	Important	Somewhat Important	Not very important	Completely unimportant
Math skills	1	2	3	4	5
Verbal Communication skills	1	2	3	4	5
Writing skills	1	2	3	4	5
Team work	1	2	3	4	5
Critical thinking	1	2	3	4	5
Organization	1	2	3	4	5
Creativity	1	2	3	4	5

How great do you think the time commitment outside of class will be for this program?

Please circle one:

0-5 hours per week 6-10 hours per week

11-15 hours per week 16-20 hours per week

20+ hours per week

You may have several motivations for entering this program. Please circle the **one** motivation that is the greatest for you:

Interest Desire to make a difference (social good)

Money Parental influence

Prestige Other _____

Demographic Info

Gender: M F

Age: _____

Race: Caucasian Hispanic African-American

Native American Asian Other _____

Major: Electrical Engineering Mechanical Engineering

Biomedical Engineering Electrical Engineering Technology

Mechanical Engineering Technology

Other _____

Home state: _____

Do you have a close relative who is an engineer? Y N

If yes, what is their relation to you? _____