# Student Perceptions of Engineering after a K-12 Outreach--a "STEM Academy"

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## Abstract

For the past 3 years, engineering students from Ohio Northern University have spent a full day running STEM activities with 4th-6th graders at a public middle school, which has been called a STEM Academy by the organizers and participants. The academy begins with a guest speaker who gives a presentation on a topic under the STEM umbrella, then students participate in multiple activities that typically involve science or engineering. While these academies had been received positively by the faculty, the effectiveness of communicating engineering to the students was uncertain. Is one day of activities truly enough to clear misconceptions of engineering?

In a post survey after the activities had concluded, students were asked questions in a similar fashion to the "Draw an Engineer Test." The sample was composed of 6th grade students (N=60 with 27 boys and 33 girls) at a small public middle school. The 6th grade students were selected by the investigator in particular in order to draw comparisons to a similar outreach previously done at another school. Responses from the survey provided insight as to how effective a STEM Academy is at informing students about engineering with its current model. Common misconceptions arose frequently in addition to common trends. The misunderstandings surprisingly manifested as the resistance of students to explore a new field by not deviating from their idealized profession. Also, students were drawn to engineering based on misinformed perceptions, particularly the activities. Suggestions based on this study can lead to improvements in how such an outreach is conducted to properly introduce students to STEM, particularly engineering.

This paper will present the results of the first survey and provide discussion on student responses. Comparisons between other outreaches will be made to establish the nature of a STEM Academy in contrast to other K-12 programs designed to promote student interest in science and engineering. Suggestions to improve the effectiveness of STEM academies will be briefly noted along with steps to meaningfully compare advancements in student perceptions for future efforts.

## Introduction

While the idea of sharing the excitement and dynamic workings of engineering is not a new idea, it has taken multiple forms with varying degrees of effectiveness. Schools have gone as far as integrating engineering into the curriculum, such as Project Lead the Way (PLTW).[1] Working

down, STEM summer camps and other out of school science activities have been used to increase student awareness of engineering and encourage them to eventually pursue a STEM degree .[2,3] Cutting back even farther, the idea of a "STEM Academy" is a colloquial term for a K-12 outreach that consists of hands on engineering activities and a guest speaker who presents on a topic in STEM. While the intentions of these "STEM Academies" are noble, it's possible that value is lost when such little time is spent exploring engineering skills. The most concerning issue is the development or affirmation of student misconceptions of engineering.

Small outreaches have been successful; for example, a project such as "Engineering Adventures" could include multiple modules covering a wide array of topics ranging from product design to controlling invasive species.[3] It has been demonstrated through quantitative studies that these modules do indeed provide a positive impact on student learning and motivation to study engineering [4]. However, these programs are long term and often require large amounts of time dedicated to running the modules with students. Determining the impact of a single session on student perceptions of engineering would allow curricula designers to make informed decisions on the value of short term STEM academies and adjust accordingly.

Student perceptions are often examined using the Draw an Engineer Test (DAET). [5,6,7] In this simple exercise, the participants are instructed to draw an "engineer at work." Space below the picture is often given to allow the student to describe what the engineer is doing in the picture. While the basic premise of the DAET is fairly straightforward, different investigators have modified this test to serve answering various hypotheses concerning student perceptions. For example, Karatas's test included asking a series of questions to supplement the drawing, such as "what is the difference between science and engineering?"[7] From this test, it is evident that students are drawing references from our culture to manufacture an abstract for an engineer. In Knight's results, most of the responses do have some overlap, especially with equating engines with car engines, meaning engineers are car mechanics.[5] While the target participants of the DAET are often elementary school or middle school students, it is no surprise that misconceptions are overwhelmingly present in their depictions of engineers.

Mass media is likely the first exposure to engineers that this age group experiences. In fact, Yurtseven in his article on the imagine of engineering with respect to recruitment explains: "as engineers, we see ourselves as bright, articulate, honest, responsible, conscientious and capable[;] the US public version of our image as engineers is... too bright for our own good, honest to a fault, non communicative, dull, and loners." [9] The concept of molding the idea of an engineer into the minds of elementary school students has been shown through the DAET, but even more concerning is the public idea of the female engineer / scientist. The majority of the DAETs capitalize on the point that a female engineer is rarely drawn, if at all, by male students. Despite the fact that girls are more likely to draw female engineers, it is not a guarantee.[6,7,9,10] Steinke examined the roles of female scientists in the media and found that women in STEM fields are often portrayed as "distractions" in addition to being generally attractive and holding multiple personal conflicts (resulting in an unbalanced work-personal life).[11,12,13] Another study offered contradictory results which claim that gender stereotypes are fairly neutral.[14] While the methods are certainly different, textual analysis of film and television shows can offer some mixed results.

## Motivation and Methods

From a previous study to examine student perceptions of engineering,[15] the idea to continue collecting qualitative data on students expanded to a "STEM Academy" run by Ohio Northern University. The initial sample was fairly small, so a larger size was intentionally chosen for this purpose. Instead of utilizing a DAET test, the investigator chose three guiding questions to begin studying student perceptions. While not a complete survey, the instrument was designed to probe the sample for any interesting trends. The three questions were the following:

- *"What does an engineer do?"*
- *"How would you describe engineering to a friend?"*
- *"Do you want to be an engineer when you grow up? Why?"*

Using the definition of engineering and engineering technology from ABET as a basis for discussion, the more significant verbs can be captured. The terms are defined as follows:

"**Engineering** is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind." [16]

"**Engineering Technology** is the part of the technological field that requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer." [16]

When the significant terminology and statements are pulled out, the different dimensions of an engineer emerge. Based on the various DAET results, the misconceptions arise in the definition of engineering technology with the troublesome sentence, "[engineering technology] lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer." [5,6,7]

To the students, the term craftsman has quite a few synonyms associated with it--including machinist and mechanic. This raises concern that students are reaching their definition of engineering far outside the spectrum. A quick search of synonyms for "craftsman" yields the following 6 terms in particular (in addition to journeyman, wright, master, skilled worker):

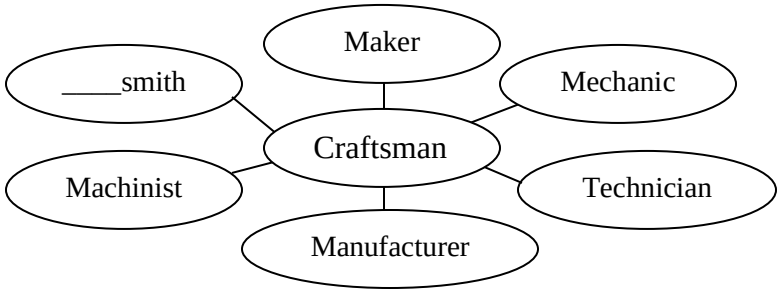


**Figure 1: Synonyms for Craftsman**

When such a wide variety of terms can be applied to craftsman, it is likely students can trace this erroneously back to the definition of engineering rather than engineering technology. The answers from the 60 students surveyed allowed the investigator to sort through the responses and classify the responses into the two distinct categories of engineering technology and engineering. To reduce the possibility of a response bias, the surveys were administered by the classroom teacher rather than the investigator.

## Results

*"What does an engineer do?"* and *"How would you describe engineering to a friend?"*

Both the first and second questions prompted students to describe what an engineer does, a less visual DAET (but with the same intentions). These questions focused on exactly what an engineer's job involves, so the verbs used by the students were culled and compiled. The students used 22 total unique verbs when results of both questions are considered together. While some repeated verbs were inevitable, the second question generated extra verbs not used to describe what an engineer does.

**Table 1: Verbs Used to Describe the Actions of an Engineer by Students**

| Verb | Male | Female | Male | Female | Total |
|---|---|---|---|---|---|
| | What does an Engineer do? | | Describe Engineering to a Friend. | | |
| Build | **16** | **14** | 16 | 9 | 55 |
| Make | 3 | 9 | **6** | **12** | 30 |
| Experiments | 3 | 2 | **3** | **6** | 14 |
| Come Up With New Ideas / Brainstorm | 2 | 2 | **2** | **3** | 9 |
| Help | 1 | 2 | **1** | **4** | 8 |
| Fixes | **2** | **3** | 3 | 0 | 8 |
| Create | **4** | **1** | 0 | 2 | 7 |
| Use (Math and Science) | 1 | 0 | **3** | **2** | 6 |
| Design | **2** | **2** | 0 | 1 | 5 |
| Work | **0** | **2** | 0 | 1 | 3 |
| Learn | **0** | **2** | 0 | 0 | 2 |
| Teach | **0** | **1** | **0** | **1** | 2 |
| Construct | **1** | **0** | 0 | 0 | 1 |
| Think | **0** | **1** | 0 | 0 | 1 |
| Use (Their Imagination) | **0** | **1** | 0 | 0 | 1 |
| Invent | **1** | **0** | 0 | 0 | 1 |
| Plan | **0** | **1** | 0 | 0 | 1 |
| Wire Things | 0 | 0 | **1** | **0** | 1 |
| Does Science | 0 | 0 | **1** | **0** | 1 |
| Solve Problems | 0 | 0 | **1** | **0** | 1 |
| Test | 0 | 0 | **0** | **1** | 1 |
| Control | 0 | 0 | **0** | **1** | 1 |

The most common verb to describe the actions of an engineer was "build" with "make" not too far behind, unsurprisingly. Instead of capturing the definition of an engineer, the students chose to focus on engineering technology. Despite the uninspiring amount of build's and make's, there were quite a few instances of students citing the appropriate roles of an engineer such as "come up with new ideas / brainstorm" and "help [people/society]." While not as prevalent in the first question, students more often included helping society or people as a descriptor of an engineer for the second question, particularly females.

Other verbs used by students are unusual or broad, such as "teach" or "control." Infrequently used verbs included "test," "invent," and "design."

*"Do you want to be an engineer when you grow up?"*

In the last question, students were asked if they would like to be an engineer when they become old enough. The participants were given the options "yes," "no," and "maybe" with space to explain their answer. Gender was taken into account, similar to the previous two questions. The responses are depicted in Figure 1. (60 responses with 27 males and 33 females)

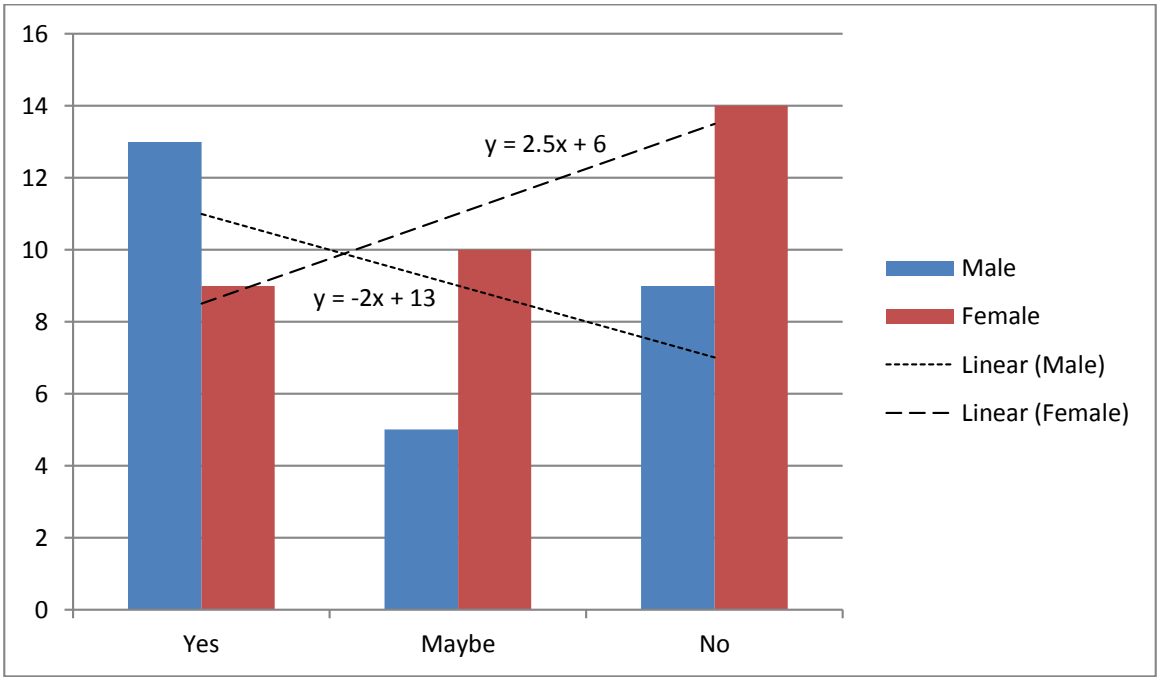


**Figure 1: Student Responses to "Do you want to be an Engineer?"**

When gender is disregarded, the columns reduce to a fairly divided pool of answers with 22 students considering becoming engineers, 23 opposed to the idea of pursuing engineering, and 15 students unsure. This deadlock is eliminated when the responses are split by gender; in fact, a distinct trend emerges, more boys respond with wanting to be engineers than girls. Unsurprisingly, the female column gradually increases as the responses became more negative to engineering. Student explanations provide insight as to why each of these responses were chosen.

**Table 2: Classified Responses by Gender**

| Reasoning | Male | Female |
|---|---|---|
| **YES** | | |
| "I'm good with my hands" | 2 | 0 |
| "I want to build houses, buildings, etc." | 4 | 2 |
| "I think it's fun to teach kids" | 0 | 1 |
| "I love watching stuff come together" | 1 | 0 |
| "I would like to build a robot" | 4 | 0 |
| "I want to follow in my brother's footsteps" | 0 | 1 |
| "I like art" | 0 | 1 |
| "Because of robot football" | 1 | 0 |
| "Makes good money" | 1 | 0 |
| "Seems cool" | 0 | 2 |
| "Because I'm creative" | 0 | 1 |
| "I like to help people" | 0 | 1 |
| **MAYBE** | | |
| Idealized Profession or Career | 2 | 4 |
| Self-Efficacy | 0 | 2 |
| "Engineering is dangerous" | 0 | 1 |
| "Looks fun" | 0 | 2 |
| "Seems interesting" | 2 | 1 |
| "I like experiments" | 1 | 0 |
| **NO** | | |
| Idealized Profession or Career | 6 | 7 |
| Self-Efficacy | 1 | 2 |
| "Engineering is difficult and a lot of work" | 1 | 2 |
| "Not my kind of job" | 1 | 0 |
| "Not into Engineering" | 0 | 1 |
| "Engineering is dangerous" | 0 | 1 |

While the first two questions are meant to examine the student's perception of an engineering, the more personal, "do you want to be an engineer when you grow up" provides the reasoning based in the first and second questions.

*I want to be an engineer*

Students who expressed interest in an engineering career most commonly cited their desire to build houses or machines. Two male students added that they are "good with their hands," so an engineering "must be right for [them]." One activity in particular featured a showcase of Robotic Football, which resulted in one student explicitly stating his interest in engineering was due to that specific exhibition. Four others expressed interest in building robots in general.

From the humanitarian aspect, one female student would like to be an engineer to help people. On the other end of the spectrum, a male responder was more concerned about the monetary benefits of engineering.

When referring to ABET's definition of engineering and engineering technology, students seem learn toward the idea of engineering technology while mentioning the ideas of engineering in particular, such as designing for the benefit of humanity.

*I may want to be an engineer*

Students were not forced to make a definitive yes or no with this question. Those who were indecisive dipped into both sides (yes and no) for reasons to be or not to be an engineer. Five interested students commented that engineering "seemed interesting" or "looks cool." More negative or concerned reasons commonly fell under the umbrella of self efficacy (2 instances) or an idealized profession (6 instances). We will define an idealized profession as the "dream job" of the student, and no amount of convincing causes the student's opinion to waver. Some responses had a mixture of problems with self efficacy and an ideal profession such as: "I am not sure because I am not good with machines, and I have my mind set on something else." One student in particular summed up the attitude of responses in this category: "maybe because it looks fun but there are a lot of other jobs but engineering." It is difficult enough for a student to decide on a major in college, so why should sixth graders be expected to commit to this profession?

*I don't want to be an engineer*

While students who responded with some interest in being an engineer when they grow up were at writing positively about the field. Responses in this category contain far more concentrated instances of idealized professions (13 instances) and self efficacy (3 instances). Three students opted out of the engineering field due to the difficulty of the job and the amount of work associated with it. Two students stated that engineering is just not for them.

*Prevalence of Idealized Professions*

With the case of students focusing on "dream jobs," the effect of STEM Academies could diminish substantially. In the sample of 60 students, 19 responses mentioned their intentions of pursuing a different career. Targeting these students is a challenge due to their stubbornness in accepting another career choice, so care needs to be taken when trying to encourage a particular profession like engineering.

## Conclusion

As an expansion of the previous effort using the same instrument, albeit some minor tweaking (asking for gender) and a larger sample size, similar results were achieved as in the literature. A rising trend in idealized professions and self efficacy with respect to engineering, math, and science is apparent when students are asked about their future plans, if any. While there is a lack of a pre-test, plans to visit the same school to run a similar program are in motion. Therefore, a pre and post test is feasible to perform in order to strengthen the data from the previous outreach.

In order to improve the STEM Academy, it may be beneficial to not rush into the activities. Instead, the activities should be grounded with a lecture to ensure the students understanding

exactly what the activity is about. Also, mentioning the nature the engineering can potentially clear up misconceptions that students infer for themselves based on disjoint STEM activities with no appropriate information to back them up.

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### *Bibliographic Information*


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