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Effect of an Engineering Camp on Students' Perceptions of Engineering and Technology

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Abstract

Students' knowledge about a profession influences their future decisions about careers. Research indicates that students tend to hold stereotypical views of engineers, which would hinder engineering as a career choice. The purpose of this study was to measure how participating in a week long engineering summer camp affected middle school students' ($N=19$) attitudes towards engineering and their conceptions of engineering and technology. Results indicate that participation in the programs had a positive impact on the students' understandings of what technology is and the work engineers do. Although the results indicate a positive impact on participants, it is not clear which components of the camp contributed to this change. The partnership between practicing middle school teachers and engineering faculty was important to the success of the camp, revealing the benefits of collaborative efforts between K-12 educators and engineering professionals.

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Introduction

According to the US Bureau of Labor Statistics (2014), occupations in Science, Technology, Engineering, and Mathematics (STEM) are projected to grow 13% between 2012 and 2022, whereas non-STEM occupations are only projected to grow 11%. STEM degree holders typically have higher salaries and lower unemployment rates than non-STEM degree holders. Furthermore, STEM workers play a vital role in promoting economic growth and stability of the US economy (US Department of Commerce, 2011). Owing to its key role in product development and innovation, engineering is important for the continued improvement of humanity. This, coupled with a large wave of future engineering retirees, makes the recruitment of diverse, highly qualified high school graduates extremely important (National Academy of Engineering & National Research Council, 2009).

It has been over 30 years since the National Science Foundation released the report, *Educating Americans for the Twenty-First Century: Report of the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology* (National Science Foundation, 1983) that sparked a movement calling for all Americans to become science literate. This report clearly documented that the "E" was the only one of the four STEM disciplines not represented in the

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assessment of the quality of precollege STEM education. In fact, engineering is the only STEM discipline that does not have its own set of national content standards. Efforts have been made, however, to integrate engineering within technology and science standards (Achieve, Inc., 2013; International Technology Education Association, 2000).

Research has suggested that one of the benefits of PK-12 engineering education is the improvement of students' ability to apply mathematics and science skills (Committee on K-12 Engineering Education, 2009). Until recently, teachers in the United States have focused on mathematics and science coursework as the way to encourage students to enter the engineering pipeline (National Academy of Engineering & National Research Council, 2009). However, this focus on mathematics and science has not resulted in enough students who enter post-secondary engineering programs to meet projected job demands. According to Social Cognitive Career Theory, individuals choose career paths based in part on their interests, attitudes, and values (Lent, Brown, & Hackett, 1994). Further, interest in STEM occupations has been linked to students' knowledge of STEM careers (Robinson & Kenny, 2003). The lack of students entering engineering programs may be attributable to a lack of understanding of what type of work engineers perform.

There is a plethora of research related to students' attitudes towards science (i.e., Jones, Howe, & Rua, 2000; Osborne, Simon, & Collins, 2003), mathematics (for example, Weinberg, Basile, & Albright, 2011; Zambo & Zambo, 2006), and the impact of outreach programs on those attitudes (i.e., Oliver & Venville, 2011; Stake & Mares, 2001). However, the literature pertaining to students' attitudes towards engineering is somewhat limited. Much of the work pertaining to perceptions of engineers has focused on elementary students' participation in the *Engineering is Elementary* curriculum developed by the Boston Museum of Science (Cunningham, Lachapelle, & Lindgren-Streicher, 2005). The existing dearth of research focused on middle school students' attitudes towards engineering and technology makes the current study an important addition to the field. This study attempts to address a void in the literature by examining the impacts of a summer engineering outreach program on middle schools students' attitudes toward conceptions of engineering and technology.

Purpose and Rationale

There is an emerging, yet limited, body of work related to the impact of summer outreach programs on students' perceptions of engineering. Studies focused on attitudes towards engineering can not only identify student perceptions of engineering, but also lead to a better understanding of the reasons why those perceptions exist. Identifying reasons behind student perceptions could help lead to interventions to improve student attitudes towards engineering and eventually result in more high school graduates pursuing engineering degrees.

The goal of the summer camp was to engage middle school students in hands-on, age-appropriate activities that would:

- allow students to differentiate between the activities of scientists and engineers,
- introduce students to engineering as a possible career path, with a focus on the field of chemical engineering,
- engage students in collaborative, problem-based learning assignments that integrate mathematics, science, and engineering, and
- provide examples of how engineers engage in engineering design to solve problems.

The purpose of this study was to determine how participating in an engineering summer camp affected middle school students' attitudes towards engineering and their conceptions of engineering and technology. Our primary research question addressed in this study was: How does participating in an engineering summer camp impact middle school students' attitudes towards and conceptions of engineering and technology?

Background Literature

K-12 Student Perceptions of Scientists and Engineers

Draw-a-Scientist (DAS) (Mason, Kahle, & Gardner, 1991) and, more recently, Draw-an-Engineer (DAE) (Knight & Cunningham, 2004) instruments are commonly used to identify students' perceptions of scientists and engineers, respectively. DAS and DAE require students to draw a scientist or engineer at work, and often ask the students to describe what they have drawn. Because students often confuse engineers with other occupations, such as scientists (Karatas, Micklos, & Bodner, 2011), it is expected that parallels can be drawn between the two.

Analysis of drawings from DAS highlight various stereotypes associated with science. For example, in a study of 1600 middle school students, Fralick, Kearn, Thompson, and Lyons (2009) reported that 33% of the students drew female scientists. Likewise, when asked to draw a picture of a scientist, Cavallo (2007) reported only five out of 150 fourth through sixth grade students depicted female scientists in their drawings. Additionally, research findings indicate that many individuals hold stereotypical views of scientists as individuals who lead solitary as unappealing lifestyles. Cavallo (2007) administered the DAS to 150 middle school students whose most common images were of lonely white men who often had crazy hair or monster-like features. In a survey of high school students, Miller, Blessing, and Schwartz (2006) found that participants viewed scientists as uncaring and passionless loners. Furthermore, the girls in their study tended to perceive scientists as unsociable individuals who do not benefit society (Miller et al., 2006).

Studies implementing DAE have reported similar findings as those using DAS. For example, Fralick et al. (2009) reported that only 13% of the 1600 participating students drew female engineers. Similarly, in a study of 20 sixth-grade students conducted by Karatas et al. (2011), only one student drew a female when asked to draw an engineer at work. Knight and Cunningham (2004) reported higher percentages of DAE images that portrayed females in their drawings (39%); however, most of these drawings came from a classroom where two female engineering college students worked with the children. Likewise, students participating in an after school engineering program for girls were more likely to depict female engineers in their drawings (Hammack and High, 2014); however, it is important to note that all of the engineers involved in the after school program were female and may have served as the basis for the participants' drawings. Moreover, DAE images suggest that students tend to view the job duties of engineers as fixing machines, building things, and driving trains (Fralick et al., 2009; Cunningham et al., 2005; Knight & Cunningham, 2004). It is reasonable to believe that these stereotypes stem from a lack of knowledge about scientists, engineers, and the nature of engineering.

Influences on Career Choice

Students' prior knowledge about a profession influences their decision to pursue that profession. For example, Wyss, Heulskamp, and Siebert (2012) reported that viewing recorded video interviews with STEM professionals had a positive impact on middle school students' interests in STEM careers. Additionally, students begin making decisions about careers as early as middle school, so providing information about STEM careers prior to and during the middle school years is important (Wyss et al., 2012). Thus, elementary- and middle-level students need more exposure to STEM initiatives, which can only be successful if their teachers know how to implement STEM materials into the curriculum (DeJarnette, 2012). In a recent study, high school and college students described that the most important factor influencing their career choice was a personal interest in the area, which was primarily due to the STEM knowledge of teachers and school counselors and parental influence about the career (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011). Additionally, Maltese and Tai (2010) reported that nearly 40% of science professionals and graduate students reported school-related factors, such as teachers, as the reason for their science interests. Because teachers play an important role in shaping adolescents' views of STEM, it is important that teachers are also knowledgeable of STEM careers.

Although adolescents report the influence of parents, teachers, and counselors on their career choices, these individuals often lack knowledge of STEM careers that is needed to properly advise students. In a study conducted by Hall et al. (2011), parents rated their knowledge of STEM areas lower than other career fields, whereas 61.3% of high school STEM teachers and counselors did not feel knowledgeable of engineering careers. This points to the limited understanding some high school counselors and teachers may hold about science.

Programs to Improve Attitudes Toward STEM

There are numerous studies pointing to the benefits of science outreach programs on students' attitudes towards science (for example, Cavanaugh, 2007; Metin & Leblebicioglu, 2011; Rahm, Moore, & Martel-Reny, 2005; Robbins & Schoenfisch, 2005) and mathematics (for example, Weinberg, Basile, & Albright, 2011). Engineering and/or technology focused camps have been found to have positive impacts on students' views of engineering (Elam, Donham, & Soloman, 2012; Nadelson and Callahan, 2011) and technology (Nugent, Barker, Grandgenett, & Adamchuk, 2010). Additionally, outreach programs that incorporate engineering into the school curriculum have had positive impacts on students' views of engineering (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009). Plant et al. (2009) investigated the impact of using computer animated interface agents on 106 middle schools students' math performance and attitudes towards the utility of math and hard sciences and found that interacting with a female agent resulted in fewer gender-related perceptions of engineering in male students, but female students' perceptions remained unchanged. Hirsch et al. (2007) reported that middle school students who were exposed to engineering within their school math and science curriculum had more positive attitudes towards engineering and a greater knowledge of engineering careers than students who were not exposed to engineering concepts within school curriculum. Unlike Hirsch et al. (2007), Mooney and Laubach (2002) reported that participating in a one to three-week-long inquiry-based engineering curriculum units within science and math curriculum had limited impacts on students' attitudes towards engineering, with attitudes declining for some female subgroups. However, Mooney and Laubach (2002) reported improved attitudes towards mathematics and science after participating in the engineering curriculum, with some male students showing improved attitudes towards engineering.

Although the previously mentioned studies point to the benefits that some engineering outreach programs have for middle school students, the diverse results and limited number of studies point to a need to further research on the impacts of middle school engineering outreach programs. Similarly, a deficit still exists in the research literature on studies devoted solely to the impact of middle school engineering camps, particularly camps devoted to the field of chemical engineering. As such, our understanding of the impact of chemical engineering outreach programs on students' attitudes toward engineering is limited.

Pedagogical Content Knowledge and Co-Teaching

Effective instruction requires both subject matter knowledge and pedagogical content knowledge (Shulman, 1986). Pedagogical content knowledge can be defined as "the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). Teachers with increased subject matter knowledge and pedagogical content knowledge are better able to determine their students' understanding of a topic and make changes to instruction that improve student learning (Bischoff, 2006).

Co-teaching can be used to allow individuals with expertise in different areas to work together to teach a course. This is commonly seen in K-12 classrooms between a general education and special education teacher. There are many proposed benefits of co-teaching (for example, smaller student-teacher ratio, more feedback to students, more individual or small group instruction); however, little research exists on the effectiveness of co-teaching at the K-12 level (Sweigart & Landrum, 2015) and there is an absence of literature related to university and K-12 teachers engaging in co-teaching.

Methodology

This study utilized a repeated measures design in which survey and content tests were given before and after participating in a summer engineering camp. The quantitative survey data were used to test the hypothesis that participation in the camp positively impacted students' attitudes towards mathematics, science, and engineering. Additionally, open-ended questions were used to further explore students' understandings of engineering and technology. Both quantitative and qualitative data were used to compare results and bring greater insight into the problem than by using a single method.

Setting and Participants

Participants included 19 students (female=4, male=15; white=18, multi-racial=1, special needs=1) who had just completed sixth grade at the middle school where the camp was held. The middle school was located in a Midwestern town of approximately 45,000 people and served approximately 750 sixth- and seventh-grade students at the time of this study. The camp was open to all students enrolled at the middle school. There was a small fee to attend the camp, but scholarships were available to those in need to ensure that socioeconomic status did not prevent participation.

Intervention

The summer engineering camp met for 3.5 hours each day for four days. Two middle school science teachers and a chemical engineering professor from a local university facilitated the camp. The middle school science teachers both held at least a bachelor's degree in a science content area. The chemical engineering professor selected the activities and assisted the teachers in the implementation. Each of the activities required students to implement engineering design and introduced students to the types of activities engineers perform. There was a large emphasis placed on chemical engineering owing to the experiences of the professor in that area. The students completed the following activities during the camp:

- **Day 1.** Students completed preassessments and then participated in a brief measurement practice activity to ensure that they could use graduated cylinders for measuring volume and digital scales for measuring mass. Next, the chemical engineer lead a discussion on the similarities and differences between scientists and engineers. Students then completed a candy airplane activity in which they built a model of an airplane using only the provided supplies (for example, candy, toothpicks, paperclips, rubber bands) within a limited amount of time. After building the model, the students mass-produced the design. The chemical engineer led a discussion over product and process design using the information in Figure 1 (Cheville & Bunting, 2011). The importance of process design in chemical engineering was discussed. One of the major features of process design that was discussed was its use with the mass production of products.
- **Day 2.** Students completed a popcorn challenge in which they built a filter for a movie theater that could separate popped and unpopped kernels and allow the unpopped kernels to be recycled. The chemical engineer led a discussion about chemical processes and recycling using the information in Figure 2. There was a discussion of how the popcorn flowchart corresponds with a chemical flowchart that would be used by a chemical engineer. After completing the popcorn challenge, students were introduced to a slime activity. During this activity, students made slime, observed its characteristics, and then created a new product that utilized the slime. Students also created an advertisement for their product. This activity was used to demonstrate the differences between scientists (chemists) and engineers (chemical engineers). On this day, students made a single batch of slime, much as a chemist would do when identifying the formulation of a new chemical substance.
- **Day 3.** Students finished the slime activity by working as chemical engineers to design, package, and market a product that made use of the slime. We also discussed the role that chemical engineers play in the mass production of chemicals that are required to be used in certain products, such as pharmaceuticals and petrochemical.

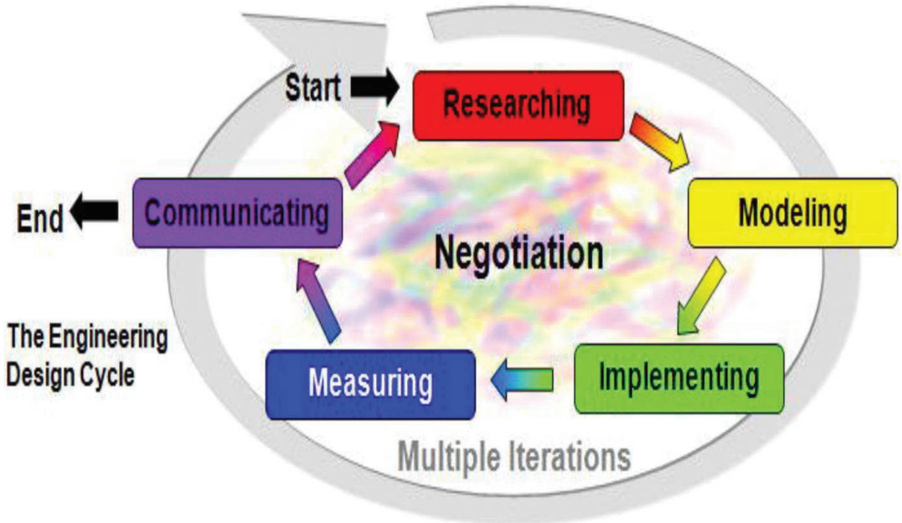

Figure 1. Engineering design process used throughout the summer camp.

- **Day 4.** Students experimented with materials to determine which reactants would make the best propellants for film canister rockets. Students designed a rocket body to attach to their film canisters, and tested their chosen propellants. A chemical engineer's role in the development and testing of rocket propellants was discussed as well as the importance of mass production of propellants.

Prior to each activity, students were presented with a problem scenario. Then, they had to complete a design challenge to address the problem. For example, prior to the candy airplane activity, students were told that an aircraft manufacturer was planning to expand its operations and was looking for a new airplane model and manufacturing facility. Students then designed a model aircraft to present to the manufacturer and then mass-produced their design. Each scenario provided students with a real world context in which engineers would work. Upon completion of each activity, facilitators discussed how students engaged in engineering design throughout the activities they created and reiterated real world applications of the concepts.

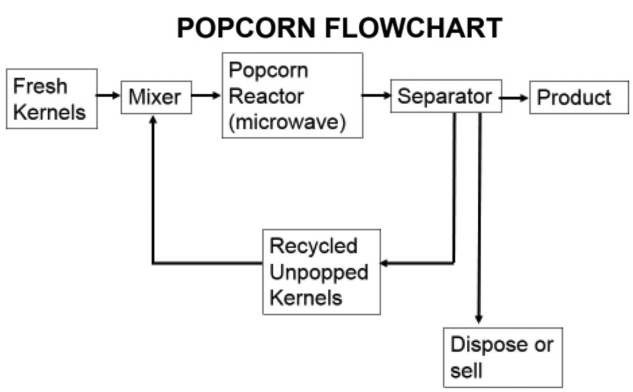

Figure 2. Flowchart used to explain the process in the popcorn activity.

Instruments

Researchers used a variety of instruments in order to measure the impact of the program on the participants' attitudes toward mathematics, science, and engineering; conceptions of technology; and conceptions of engineering. These measures are described in detail below.

Attitudes to Mathematics, Science, and Engineering (AMSE). The AMSE is a 5-point Likert-scaled instrument consisting of 36 items that are categorized into 8 subscales. Table 1 provides a list and description of each subscale, including the range of scores. Scores on the overall AMSE can range from 36 to 180, with higher scores being indicative of a more positive attitude toward mathematics, science, and engineering (Hirsch et al., 2007). Illustrative items include "Engineers are just people who do a lot of math and science" and "Engineers help make people's lives better."

What is Technology? Cunningham and colleagues (2005) developed the *What is Technology?* instrument to assess elementary students' conceptions of technology. The instrument consists of images and names of 16 items and one open-ended item: How do you know if something is technology? Participants circle the images they associate with technology and complete the open-ended response. Example items are *shoes*, *cellular phone*, and *bird*. Scores provide data related to participants' ability to correctly identify examples of technology, which can help researchers identify misconceptions held by participants.

What is Engineering? Cunningham and colleagues (2005) also developed the *What is Engineering?* Instrument, which consists of 16 images and descriptions of people at work and one open ended response: What is an engineer? For this instrument, participants circle the images with which they associate the work engineers perform as a part of their jobs and complete the open-ended response question. Illustrative items include *improve bandages*, *drive machines*, and *work as*

Table 1
Attitudes Toward Mathematics, Science, and Engineering (AMSE): subscales, descriptions, and score ranges.

Subscale	Description	Subscale ranges	
		Min	Max
Overall AMSE		36	180
Interest in engineering: stereotypic aspects (ISA)	Students' interest in engineering based on common stereotypes	7	21
Interest in engineering: non-stereotypic aspects (INSA)	Students' interest in engineering not based on common stereotypes	4	12
Positive opinions of mathematics and science (PO)	Students' positive opinions towards math and science	5	15
Negative opinions of mathematics and science (NO)	Students' negative opinions towards math and science	5	15
Problem solving (PS)	Students' attitudes towards their problem solving abilities	4	12
Technical skills (TS)	Students' attitudes towards their technical skills	4	12
Engineer (E)	Students' understanding of the type of work engineers perform	5	15

a team. Scores provide data related to participants' ability to correctly identify tasks completed by engineers as they work, which can help researchers identify misconceptions held about engineers.

Engineering Content Test. On the first day of the camp, participants were given a precamp content test developed by the chemical engineering faculty member. The survey contained questions about content specific to chemical engineering, confidences in participating in engineering design, and the following journal prompts: "What does a chemical engineer do?" and "Have you thought about becoming an engineer?" On the last day of camp participants completed a post-camp content test and responded to the following prompts: "What does a chemical engineer do?" and "Did camp encourage you to consider engineering?"

Data Collection and Analysis

Camp facilitators pretested all participants at the beginning of the first day of camp and post-tested on the last day of camp. All students completed the AMSE, *What is an Engineer?,* and *What is Technology?* instruments and Engineering Content test.

Quantitative Data Analysis. Owing to the small sample size and lack of a normal distribution of data, researchers used nonparametric statistics for data analysis. A Wilcoxon Signed Rank test was performed in SPSS version 21.0 for the content test score, overall AMSE score, and all AMSE subscales except the "other" subscale. Individuals' subscale scores were determined by summing all of the item responses for a particular subscale. Table 1 presents the possible ranges for an individual's subscale scores. On the presurvey, two participants left one item blank from the negative opinions of mathematics and science subscale. On the post-survey, two participants left one item blank, one from the negative opinions of mathematics and science subscale and one from the interest in engineering stereotypic aspects subscale. To account for each participant's missing value, the mean for each individual's subscales were imputed for the missing item. For example, items 4, 12, 13, 21, and 29 comprise the negative opinions of mathematics and science subscale. Participant A left item #21 blank on the pretest. His scores from items 4, 12, 13, and 29 were averaged and the resulting value was assigned to item 21.

Each participant's *What is Technology?* and *What is Engineering?* responses were scored based on the percentage of correct images that were circled. Pre and post-test percentages were entered into SPSS and a Wilcoxon Signed Rank analysis was performed. Researchers then examined the frequencies to identify trends.

Each participant's Engineering Content Test was given a score based on the percentage of items that were correctly answered. Pre- and post-test percentages were entered into SPSS and a Wilcoxon Signed Rank analysis was performed.

Qualitative Data Analysis. The open-ended response items on the *What is Technology?* and *What is Engineering?* instruments, as well as the "What does a chemical engineer do?" question were printed onto cards and examined independently by three researchers to develop a coding scheme for the responses. The researchers discussed the three coding schemes and consolidated them into a single coding scheme. The cards were independently recoded using the consolidated coding scheme. There was 95% agreement between the resulting codes; the three researchers discussed the differences until 100% consensus was reached (Emerson, Fretz, & Shaw, 1995).

Results

Attitudes to Mathematics, Science, and Engineering

Researchers calculated a Cronbach's alpha (0.86) to determine the internal consistency for the AMSE instrument; this value was consistent with the value reported (0.85) by Hirsch et al. (2007). Table 2 presents the descriptive statistics and Wilcoxon Signed Rank test results for the seven AMSE subscales. Only the Engineer subscale showed a significant difference pre to post ($Z = 0.003$, $p < 0.01$).

Table 2
Summary statistics for participants' (n=19) scores on Attitudes Towards Mathematics, Science, and Engineering Scale (AMSE).

	Pretest			Post-test				
Subscale	Min.	Max.	Mdn.	Min.	Max.	Mdn.	Z	p
AMSE-Overall	81	139	111	78	140	114	−0.829	0.407
ISA	13	32	22	9	31	24	−0.156	0.876
INSA	5	18	10	4	19	10	−0.604	0.546
PO	5	23	17	8	23	16	−1.225	0.220
NO	5	13	9	5	21	8	−0.192	0.848
PS	6	20	12	6	16	13	−0.287	0.774
TS	10	20	14	9	20	13	0.528	0.528
E	14	22	18	16	23	19	0.003	0.003**

$^{**}p < 0.01$

What is Technology?, What is Engineering?, *and Engineering Content*

Table 3 presents the descriptive statistics and Wilcoxon Signed Rank results for the *What is Engineering?, What is Technology?,* and engineering content measures. Pre- to post-test differences were significant for three measures ($p < 0.01$).

Figure 3 illustrates the percentage of items selected as correct on the *What is Technology?* pre and post measures. An examination of these percentages indicated that many participants associated technology with items that were electronic (100% selected TV and phones) or involved the use of electricity (100% selected subways, 95% selected power lines), and none of the participants associated technology with living organisms (0% selected bird, tree, or dandelions). Fewer participants associated technology with non-electrical manmade items, however a greater percentage of participants selected items that may be associated with construction (58% selected bridge, 63% selected house, 84% selected factory) than items not generally associated with construction (47% selected shoes, cups, and bandages; 52% selected books and bikes). On the *What is Technology?* Post-test, however, participants clearly associated technology with items that do not exist in nature (95% selected bandages, 100% selected shoes, subway, phone, bridge, TV, cup, factory, house, power lines, bicycle, books).

Participants' responses to the *What is Engineering?* instrument are displayed in Figure 4. An examination of student responses indicates that seven of the nine items associated with activities of an engineer (marked with an asterisk in Figure 4) increased at the conclusion of the engineering camp. These items include verbs such as improve, develop, design, and create. The other two items (i.e., Design clean water, figure how to track luggage) showed no change in the number of responses, however more than half of the students correctly selected these items. Of the seven items not associated with activities of an engineer, fewer students selected that engineers construct buildings, sell food, and clean teeth at the conclusion of camp. There was an increase in the number of students who incorrectly selected driving machines and repairing cars as acts of an engineer and over half still chose that an engineer performs the act of installing wiring. Surprisingly, two participants held on to the misconception that the work of an engineer includes arranging flowers.

Open-Ended Responses

This section present results from the qualitative analysis of an open-ended response from three data sources: (1) *What is an Engineer?* (2) *What is Technology?* and (3) Engineering Content Test. The percent occurrence of emergent themes from each data source is presented in Figures 5, 6, and 7. On the *What is Technology?* instrument, students' initial responses to "How do you know something is technology?" were categorized as electrical, manmade, or helps people. However, at the end of the engineering camp, all students' responses indicated an understanding that technology was something that is manmade. Additionally, a large percentage of students' initial responses to the prompt "What is an engineer?" were categorized as someone who builds, designs, or improves things to help people. On the post-test, however, the percentage of responses falling within these categories declined greatly, and a new theme (mass production) was identified in 68% of responses. Students' Engineering Content Test responses indicated growth in their understanding of

Table 3
Summary statistics for participant's scores on *What is Engineering?* and *What is Technology?* and Engineering Content instruments.

		Pretest			Post-test				
Instrument	n	Min.	Max.	Mdn.	Min.	Max.	Mdn.	Z	P
Engineering	19	37.5	93.75	62.5	50	100	75	−3.285	<0.001**
Technology	19	43.75	100	75	100	100	100	−2.818	0.005**
Content	19	0	57	14	29	86	57	−3.456	<0.001**

$^{**}p < 0.01$

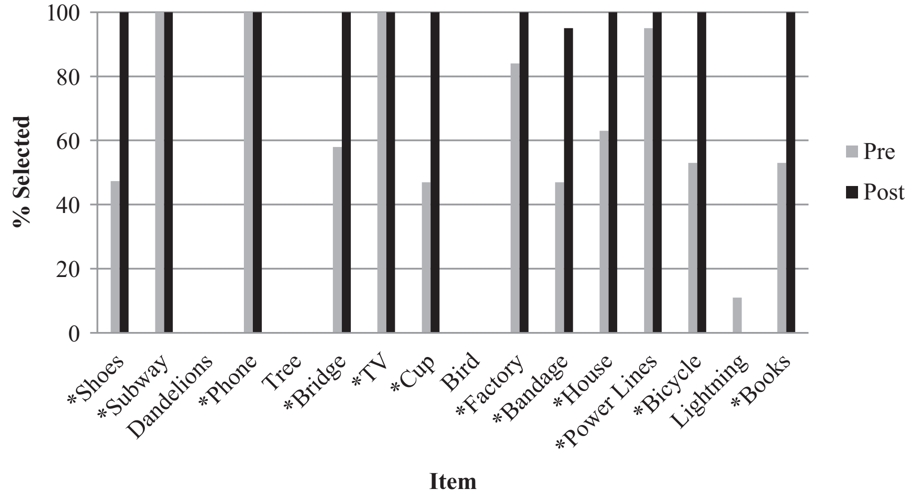

Figure 3. Frequency of participants' responses for items on the *What is Technology?* instrument. *Items that are considered technology.

chemical engineers. Examples of students' open-ended responses on the Engineering Content Test are presented in Table 4. When asked what chemical engineers do, responses of "I don't know" decreased from 26% to 5% by the end of the camp. Additionally, analysis of students' open-ended responses indicated a shift in their understanding from thinking that chemical engineers only mix and use chemicals to engaging in more complex work (i.e., experimenting) with chemicals.

Discussion

Overall, the results indicate that participants improved their (1) understanding of technology, (2) chemical engineering content knowledge, and (3) attitudes towards engineering. Of the seven AMSE subscales tested, only the responses on the Engineer subscale changed significantly. This indicates that over the course of the camp, participants' attitudes towards engineering became more positive, with more participants reporting that they know what an engineer does. These results are consistent with the open-ended response questions. Responses to the open-ended "What is an Engineer?" prompt on the *What is Engineering?* post-test indicate that participants gained an understanding of engineers as people who work in teams and mass produce products.

The scores on the *What is Technology?* instrument were significantly higher on the post-test, indicating that the camp intervention had a positive impact on the participants' understandings of technology. As evident in the frequency counts and open-ended responses, many participants began camp with the misconception that technology only included items that required electricity. These results are consistent with the findings of Cunningham et al. (2005), who found that students in grades 1–5 tend to associate technology with objects requiring electricity. By the end of camp, all participants reported that technology referred to any object that was manmade.

Scores on the Engineering Content Test were significantly higher on the post-test, indicating that the intervention had

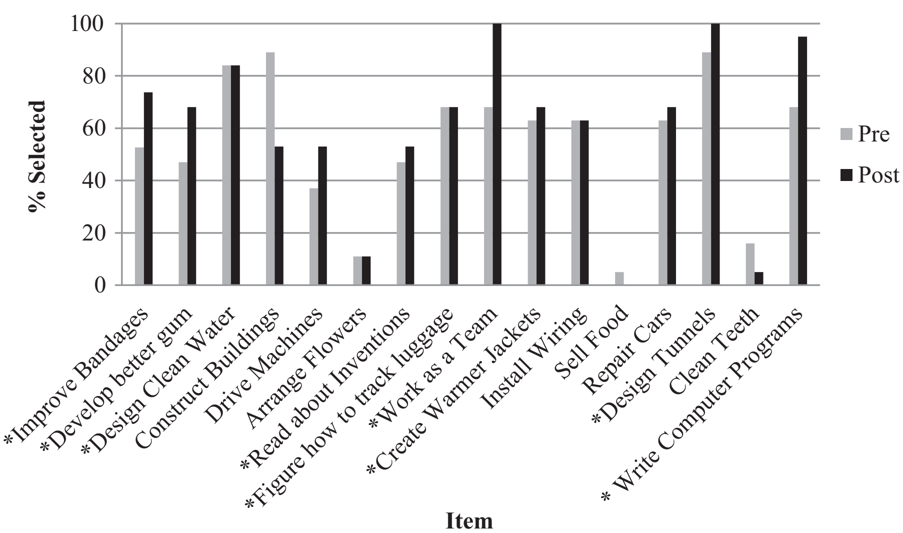

Figure 4. Frequency of participants' responses for items on the *What is Engineering?* instrument. *Items associated with engineering.

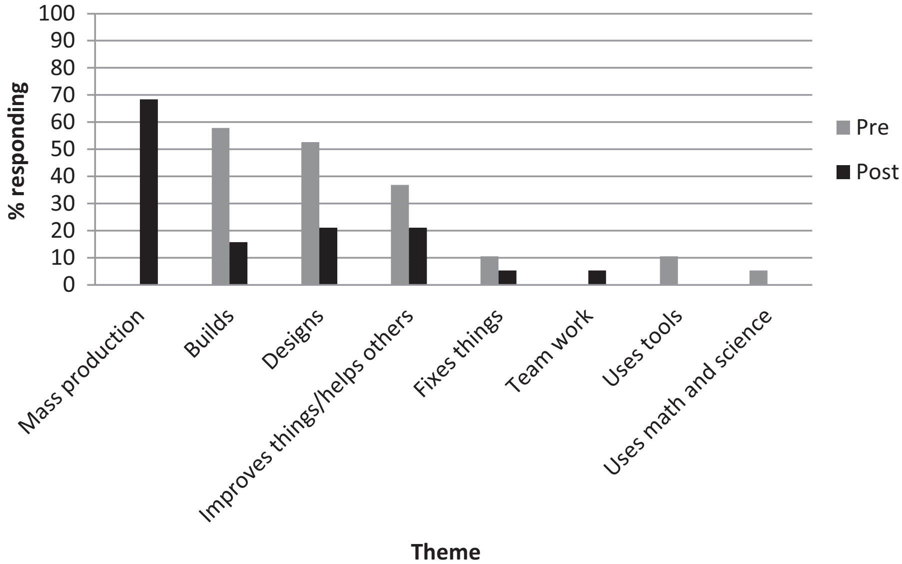

Figure 5. Frequency of themes for *What is Engineering?* instrument.

a positive impact on participants' content knowledge related to chemical engineering. Although the median post-test score was over 40 points higher than the pretest median, it was still only 57%, which is below the 70% proficiency score used by the school where the camp was held. This suggests that while participants increased their understanding of chemical engineering, they still did not master all of the content covered in camp. The short duration of camp may not have provided enough time for students to fully master the new concepts.

The range in frequencies on the *What is Engineering?* pretest point to participants' uncertainties about the activities of an engineer. There was still a large range in the post-test results, indicating that participants still had some degree of uncertainty about the work of engineers. However, there were some positive changes worth noting. Prior to participating in camp, 68% of participants viewed engineers as people who work as a team, whereas, all campers circled "work as a team" on the post instrument. All of the camp activities required that participants work as a team to solve problems, which may have accounted for this change. Recognizing that engineers are not solitary loners, but in fact work in teams to tackle important real world problems, could help combat the common negative stereotypes previously reported (Cavallo, 2007; Miller et al., 2006), and may prevent more adolescents form abandoning the STEM pipeline. Additionally, participants' Engineering Content Test responses also indicated a positive shift in their attitudes towards engineering as a career. For instance, only 26% of camp participants reported that they had considered becoming a chemical engineer prior to camp, whereas 63% of participants reported that camp encouraged them to consider chemical engineering as a career.

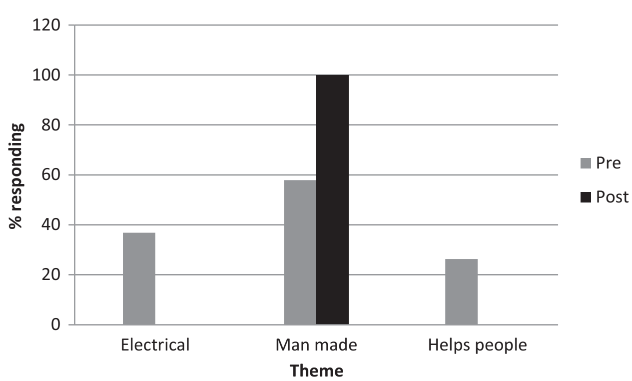

Figure 6. Frequency of themes for *What is Technology?* instrument.

Although the findings indicate an increase in the number of student considering a career in engineering, they still held many misconceptions about the work of engineers. It is important to note that the engineering camp did not explicitly address all misconceptions presented on the *What is Engineering?* instrument. However, the camp did discuss that engineers focus their work on the design and creative aspects of construction but are not the actual builders. This highlights a trend in our findings that the participants' views of engineering shifted away from engineers as mere builders, and a move towards an understanding that engineers design solutions to problems. This trend is mirrored in the open-ended responses, as nearly all participants recognized that "building" was not an act of engineering by the end of the camp. The only two "building" responses on the post-test were:

"An engineer is a person who builds a lot of one thing."

"Someone who builds lots of stuff."

It is important to note that one major focus of the candy airplane activity was the role engineers play in industry and mass production, and the mass production of chemicals was discussed during both the slime and film canister rocket activities. It is therefore not surprising that over one-half of the participants referred to mass production in their post-test responses. The two participants who wrote "build" in their post

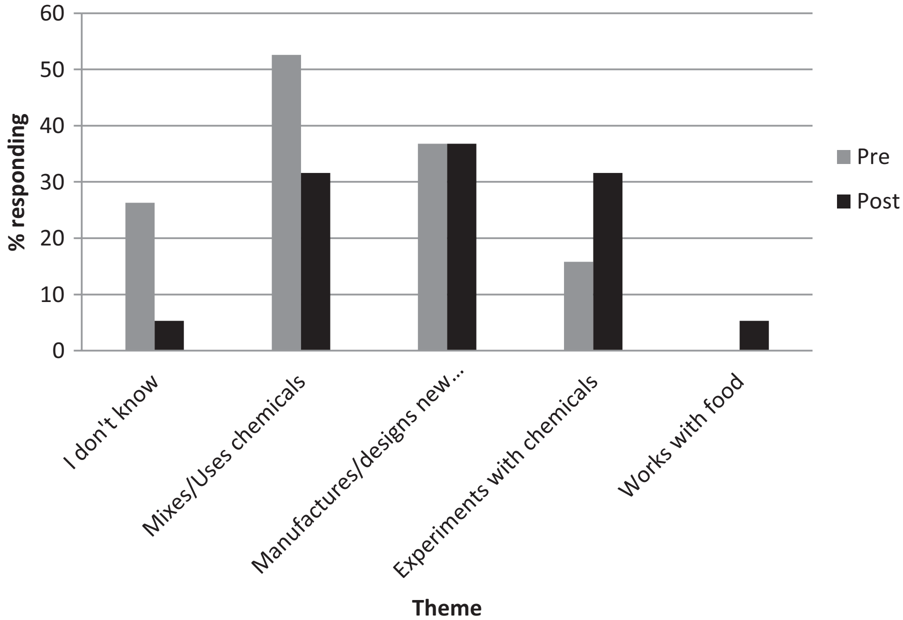

Figure 7. Frequency of themes for Engineering Content Test responses.

responses may also have been referring to mass production, rather than simply building or constructing an object.

Interestingly, there are conflicting findings between the quantitative and qualitative responses on the *What is Engineering?* instrument. Although the number of images students selected of engineers designing and improving products increased, students qualitative responses related to designing and improving products decreased. Because the

Table 4
Examples of participants' open-ended responses by theme.

Theme	Example Pre-program Responses	Example Post-program Responses
How do you know something is technology?		
Electrical	It creates energy and has circuit boards and stuff	N/A
Man made	Man invents technology, e.g. bicycle, subway.	Something that is technology is a man-made object.
Helps people	If it was invented by people to help other people.	N/A
What is an engineer?		
Mass production	N/A	An engineer creates multiple copies of a product.
Builds	Someone who builds something	Someone who builds lots of stuff.
Designs	Somebody who designs and builds stuff.	An engineer designs some product and fins a way to mass produce it.
Improves things/helps others	Someone who researches and develops innovations to make this world a better and easier place.	Someone who improves inventions.
Fixes things	An engineer is someone who fixes or creates things.	An engineer is a person that fixes things and works as a team
Team work	N/A	An engineer is a person that fixes things and works as a team
Uses tools	I think it is someone who builds or designs things, and works with tools and different kinds of machinery.	N/A
Uses math and science	People who do math and science.	N/A
What does a chemical engineer do?		
I don't know	I don't really know.	I can't describe it.
Mixes/Uses chemicals	Mixes chemicals.	Someone who works with mixing and learning about chemicals.
Manufacturing/designs new products or chemicals	Works with chemistry to make new materials	Helps manufacture chemicals.
Experiments with chemicals	A chemical engineer experiments with different chemicals to see if they do something useful or harmful.	Experiments with different chemicals to see what they do.
Works with food	N/A	Works with food.

candy airplane, slime, and rocket activities all dealt with mass production, it is possible that participants concentrated on the aspect of mass production during their open-ended responses. However, half of participants' journal prompts about the work of a chemical engineer referred to some aspect of designing or creating a product on the post-test. Additionally, there was a decrease in the qualitative responses related to "helping people" on the *What is Technology?* and *What is Engineering?* instruments. The decrease in balanced by the increase in "manmade" responses on the *What is Technology?* instrument and "mass production" responses on the *What is Engineering?* instrument.

Overall, the findings indicate that the participants gained an understanding that engineers are involved with the mass production of products as well as their design and improvement. As such, the decrease in students' responses in these categories is balanced by the increase in the number of responses that indicated engineers as mass producers of items. Follow-up interviews with participants would have been valuable as a means of providing additional information as to how participants' perceptions of engineers changed as a result of camp.

Limitations

Although the results indicate a positive impact on participants, it is not clear which components of the camp (hands-on activities, interaction with a professional engineer, combination of factors) contributed to this change. Follow-up interviews could have helped identify these factors. Campers self-selected into the program and may have already had an above average interest in STEM. This, coupled with the small sample size, limits the generalizability of the findings. Results were also limited by the instruments used. The *What is Engineering?* instrument uses a specific definition of engineering that is not universally accepted. Additionally, the validity of the content test has not been established and the test has only been used with the 19 study participants. Because we only collected and analyzed data immediately following the summer camp, our study only addresses short-term impacts. Future research should be conducted to determine long-term impacts of engineering outreach programs.

Conclusion and Implications

In answering our research questions, we found that participation in an engineering summer camp had a positive impact on middle school students' understandings of what technology is and what engineers do, evidenced by both the quantitative and qualitative data. The open-ended questions supported and added detail to the quantitative findings, providing more evidence than if either data set had been used independently. Participants' attitudes towards mathematics and science were not significantly impacted by the summer camp. However, their attitudes towards engineering were significantly impacted. The short duration of the camp limited the quantity of information that could be presented to participants, with the current intervention focusing primarily on engineering. Although measurable impacts were accomplished during the week long summer camp, long term interventions, such as the infusion of engineering activities within the school curriculum, could allow for attitudinal changes across multiple STEM disciplines.

The partnership between practicing teachers and engineering faculty was important to the success of the camp. Although the extent to which co-teaching impacted outcomes was not measured, the diverse backgrounds of the camp facilitators allowed for the combination of pedagogical knowledge and engineering content expertise to create rich engineering experiences that were developmentally appropriate for middle school participants. These experiences positively impacted participants' attitudes towards engineering, revealing the benefits of collaborative efforts between K-12 educators and engineering professionals. Additional research in this area is needed.

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