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Impact of a Summer Camp on Elementary Students' Understanding and Awareness of Engineering Careers and Attitudes toward Engineering

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ABSTRACT

Students who develop interest in STEM careers by the eighth grade are more likely to pursue careers in STEM (Tai et al., 2006). Interest development can happen through a variety of sources, including informal learning experiences such as out of school programs and summer camps. This study looks at one such informal STEM experience, an engineering summer camp for elementary students, to explore how this camp impacted their understanding, awareness, and attitudes toward engineering. The study used a pre/post design to determine the impact of the camp with two groups of students in two separate years. The results suggest that students gained an awareness of the types of engineering, a better understanding of the purpose of the work of engineers, and had more positive attitudes about the value of engineering and their own aspirations toward engineering.

Keywords: elementary engineering education, outreach, camps, attitudes

Introduction

There is a growing need to develop a workforce that is capable of meeting the needs of a changing society. The World Economic Forum (2017) recently published a report indicating that the workforce of the future will be heavily dependent on technology and engineering. The number of science, technology, engineering, and mathematics (STEM) jobs in the United States is projected to grow at a rate 4.6% higher than non-STEM jobs between 2019 and 2029 (U.S. Bureau of Labor Statistics, 2020). While the number of STEM graduates in the U.S. is steadily rising, a growing number of those graduates do not remain in the U.S. workforce, instead returning to home countries such as China and India (National Science Board, 2018). This points to a need for more US students to graduate from STEM programs to meet the job demand, which will require attracting students to STEM majors prior to entering college. A growing body of research indicates that early experiences in and out of school are effective at developing STEM interest, which in turn influences students' choices to pursue STEM careers (Maltese et al., 2014; Maltese & Tai, 2011; Sadler et al., 2012).

Interest develops at all ages; however, students are more likely to pursue a STEM degree if they develop some interest in a STEM career prior to middle school (Tai et al., 2006). This interest can develop through a variety of sources. Many people who pursue a STEM degree attribute their interest to early life experiences with a family member or friend who is an engineer or scientist, opportunities to tinker with devices or play outside, or a natural interest in the subjects (Maltese et al., 2014). Learning experiences in elementary school can also play a vital role in developing interest and understanding of the field of engineering (Burt & Johnson, 2018). Thus, students, particularly those who do not have family or community support for STEM, need opportunities to experience engineering in order to gain exposure and understanding of what it entails. Formal learning experiences in the school are the most logical setting to gain this exposure, but this is not always possible. Many elementary school teachers lack the confidence to appropriately teach science and engineering in the classroom, causing them to leave these subjects out of instruction or to insert ineffective activities into the curriculum (Appleton, 2013; Yoon et al., 2011). Consequently, informal learning experiences can offer students learning opportunities that may be limited in formal K-12 settings.

Even though we know STEM interest develops early, the research on this development among elementary students is limited. Much of the current research on early learners focuses on conceptions of an engineer (Pekmez, 2018; Newley et al., 2017; Capobianco et al., 2011; Karatas, Micklos, & Bodner, 2011) or identity (Capobianco et al., 2012; Capobianco et al., 2017). While these are important factors that play a role in students' future career decisions, they do not paint the whole picture. This is particularly true when students do not have accurate representations of engineering careers which could limit their ability to see their possible selves (Markus & Nurius, 1986) in those future roles. This study attempts to address this gap in the literature by focusing on understanding of engineering alongside career awareness and interests of upper elementary students.

This study examines an engineering summer camp for elementary students. The goals of the camp were to provide engineering experiences for students in grades 4-6, teach them about the process of engineering design, and expose them to a variety of engineering fields and career options. We pursued each of these goals to provide students with experiences that might enhance their ability to envision engineering as a future possible career path. The purpose of the study was to explore how this camp impacted elementary students' understanding, awareness, and attitudes toward engineering. The study addressed the following research questions:

1. How did the engineering camp affect student understanding of the work of engineers and awareness of engineering careers?
2. How did the engineering camp affect students' attitudes toward engineering?

Background Literature

To guide our study related to students' interest in and awareness of engineering careers, we reviewed literature on career interest development and attitudes toward engineering. Additionally, we explored research focused on student understanding of engineering and in particular their understanding of the work of engineers.

Interest Development and Career Awareness

The development of interest in engineering and engineering careers is a critical aspect of students' choice to pursue those careers. The development of this interest can happen in a variety of ways. Positive learning experiences both in and out of school, and students' beliefs and attitudes about engineering play an important role in this development (Banerjee et al., 2018; Burt & Johnson, 2018; Dou et al., 2019; Lent et al., 1994; Maltese & Tai, 2011). Several studies have pointed out that STEM interest development happens most often prior to middle school (Maltese et al., 2014; Tai et al., 2006; Wyss et al., 2012). A critical age for the development of these interests occurs in middle childhood, particularly in upper elementary school where children begin to think of their interests and capabilities as becoming solidified (Todt & Schreiber, 1998). Students also need guidance to understand that achievement and success are not strictly innate, as well as assistance with developing a growth mindset (Harter, 2006).

The development of interest in engineering and engineering careers can be increased through a variety of mechanisms. One study examined the influence of a design and build workshop with students in upper elementary and middle school. The results indicated that the experience had a positive impact on students' attitudes toward engineering, views that engineers are problem solvers and impact the world, and familiarity with engineering. Additionally, students' self-efficacy and interest in STEM increased after the intervention (Innes et al., 2012). Sullivan and Bers (2019) studied the effects of a robotics program on the interests and attitudes of early elementary students. They found that boys had a higher initial interest in engineering than girls, but after the intervention, girls' interest rose significantly. These authors also noted that the teachers for the robotics program were all female, perhaps providing positive examples for the girls in the study. Ozugul et al. (2017) examined the engineering knowledge and interest of students in grades K-5, finding that understanding of and interest in engineering were not significantly different between males and females, but Caucasian students had significantly higher knowledge and interest levels than Latino/a students. The disparity between ethnic groups can arise when students from one group have limited access to opportunities that promote STEM. These authors suggested that in order to decrease this disparity, engineering interventions should begin in early elementary school. Furthermore, they suggest these interventions should continue through upper elementary school to avoid the split in knowledge and interests in genders that commonly occurs as students progress through secondary schools.

Studies of elementary students in engineering camps are lacking, supporting the need for this study. However, there are several studies that indicate positive effects of engineering camps on interest and understanding of engineering for middle and high school students. Mohr-Schroeder et al. (2014) ran a one-week camp for middle school students that provided students with a variety of hands-on engineering and science experiences led by college faculty and local teachers. They found that their camp was engaging to participants and reported a positive change in career interest between a pretest and posttest. Yilmaz, et al. (2010) found that their camp for high school students improved engineering career interest through an interdisciplinary approach using a variety of hands-on engineering projects. These projects involved real-world scenarios and challenges where students worked in teams to complete the challenges over the course of the week-long camp. Furthermore, Kong, et al. (2013) surveyed over 1,500 middle school students from eight different schools and found that when controlling for initial interest, those who had participated in a science- or engineering-based camp were more likely to want to pursue an engineering career.

Understanding of Engineering

Engineering is a field that involves the design and support of systems and objects that make the world more efficient and productive (Trevelyan & Williams, 2019). Engineering affects every area of life and has a major impact on people of all ages. However, when asked to describe the work of an engineer, many elementary students have misconceptions or lack understanding of engineering altogether. Typical responses from students depict engineers as mechanics, fixers, or laborers, without acknowledging the role of design in the work of an engineer (Capobianco et al., 2017; Capobianco et al., 2011; Gibbons et al., 2004; Newley et al., 2017; Reeping & Reid, 2014). One reason for these misconceptions about the work of engineers is that many elementary teachers feel unprepared to teach engineering and often do not present these experiences regularly (Banilower et al., 2013), in spite of integration of engineering practices into the *Next Generation Science Standards* (NGSS Lead States, 2013) and many states' standards (Lopez & Goodridge, 2018). Therefore, the primary source of information about engineering is developed from portrayal in media or connections with engineers who are friends or family (Bevins et al., 2005; Chou & Chen, 2017; Jacobs & Scanlon, 2002). One of the issues this presents is that many students do not have any personal connections to engineers and are therefore only exposed to limited, and often inaccurate, examples of engineers. Rao and Dewoolkar (2021) examined the portrayal of engineers in the news media and found that engineers were rarely mentioned and news stories missed out on opportunities to describe engineers as experts capable of helping solve key problems. Ellestad (2013) studied popular media, finding that engineers are often portrayed as socially awkward, white males, and with exaggerated and farcical characteristics. The study found that the media furthered people's stereotypical images of engineers, even when personal experiences with engineers countered these images.

Understanding student conceptions of the work of an engineer is not always easy to do. One common method is the use of drawings to gain insight into students' perceptions of the work of an engineer. Capobianco, et al. (2011) conducted a study in which they collected data from nearly 400 elementary students in various types of schools in the Midwest. The authors demonstrated that these students often depicted engineers as mechanics, laborers, and technicians. They also found that more than half of the drawings portrayed engineers as men. Middle school students have also been found to share conceptions of engineers as predominantly males who are portrayed as makers (Fralick et al., 2009; Hammack & High, 2014; Karatas et al., 2011).

Interventions have had some success in developing an understanding of the work of engineers in students. Farland-Smith and Tiarani (2016) looked at two groups of eighth grade students, one in a traditional science classroom setting and another in which the teachers brought in engineers from the community and focused on engineering careers and the integration of STEM subjects. While both cohorts had similar misconceptions initially, the integrated STEM cohort developed a more comprehensive understanding of the work of an engineer and how an engineer uses science. Hammack et al. (2015) studied the effect of an engineering-focused summer camp on the understanding of engineering, determining that participants gained a better grasp of engineers as being involved in the design and development of products. Similarly, Hammack and High (2014) examined the impacts of an afterschool engineering mentoring program for middle school girls and found that prior to participation, students viewed engineers as people who build and fix things. After participating in the program, the girls were more likely to portray engineers as creative problems solvers.

Attitudes Toward Engineering

Elementary school students' attitudes toward engineering vary based on a variety of factors, though there is some indication that attitudes are less positive in elementary school and more positive in secondary schools (Kőycű & de Vries, 2016). Additionally, there are studies that indicate differences over whether males or females have more positive attitudes toward engineering in elementary school (Lachapelle & Cunningham, 2019; Lie et al., 2019). However, studies tend to support the notion that interventions focused on engineering education improve student attitudes toward engineering. Baran, et al. (2016) looked at an elective weekend out-of-school STEM program for middle school students. While students generally had positive attitudes starting the camp due to its voluntary nature, the program still made significant improvement to attitudes, particularly in regard to personal and social implications for engineering, use of science in engineering, and daily-life connections for STEM subjects. Another study, by Teeter, et al. (2020), examined an engineering-focused exhibition for high school students. They suggested that outreach events such as these, which focus on developing interest and engagement, improved attitudes toward engineering in conjunction with the development of identity toward engineering.

Student exposure to engineering in the classroom and informal experiences can help them to identify more closely with engineers. Kelly, et al. (2017) describe this development as a progression, from simply seeing a person acting in the role of an engineer, to actually doing the work of an engineer themselves. A study by Douglas, et al. (2014) examined students in grade 2-4 classes with teachers who had taken professional development in engineering education. The teachers implemented engineering lessons in their classes throughout the school year. Researchers found that students identified themselves as engineers more after the intervention than they had before. Another study of middle school students reported that integration of engineering into the curriculum increased students' identity as engineers (Yoon Yoon et al., 2014).

Theoretical Framework

The possible selves framework guided our work on this study. Possible selves are the ideas individuals possess about what they might become (Markus & Nurius, 1986). These possible selves include visions of who they would like to become as well as who they fear they might become. Possible selves are separate yet connected to current and past selves and are distinctly social. Perceived possible selves can be the direct result of how individuals compare themselves with the characteristics and behaviors they have witnessed of others. "What others are now, I can become" (Markus & Nurius, 1986, p. 954). While individuals might have multiple possible selves, the possible selves they create are derived from their personal experiences and exposure to different models, images, and symbols.

For children, career related possible selves can be ideas about what is possible for their future. These ideas of possible careers can then guide their behavior to help them achieve a desired outcome. Children may perceive certain possible selves to be more achievable than others based, in part, on exposure to the career and availability of role models (Oyserman et al., 1995). It is only when a hoped-for self seems possible that a child attaches certain actions to that self and can envision a path toward achieving that possible self (Oyserman & Markus, 1990). This means having limited exposure to accurate representations of different careers, such as engineering, can limit a child from developing the possible self of engineer. As such, one of our primary goals when designing the camp experiences for children was to provide them with experiences that connected the camp activities they completed with the work of real engineers. By providing campers with opportunities to learn about the work of engineers from the engineers themselves, we hoped to provide them with opportunities to envision a possible self where they could become an engineer.

Methods

The possible selves framework (Markus & Nurius, 1986) guided the design of the study intervention and our interpretation of the findings. Researchers sought to evaluate the effectiveness of the engineering summer camp intervention for elementary students by using a one-group pretest-posttest design (Strunk & Mwavita, 2020). Prior to any data collection, IRB approval was gained for this evaluation project. Thus, for each participant, researchers gained student informed consent and parent consent prior to participant data being included in this study.

This study utilized a purposeful sampling strategy that required the researchers to establish criteria for the sample prior to data collection (Hays & Singh, 2012). Further, Miles and Huberman (1994) suggest that there are a variety of purposeful sampling strategies. Based on the literature suggesting that middle childhood is a critical time for interest development, we purposefully recruited middle childhood participants for our camp. Through the selection of all participants in the summer engineering camp across two years of the camp, a comprehensive sampling method provided the most representative sample.

Participants

Camp participants (*n* = 49) came from two summer camps held in consecutive years that were organized by the study authors and included elementary students who were going into grades 4-6 the next academic year. Only 44 camp participants were included in data analysis as five were lacking either a complete data set or parental consent to be included in the study. Table 1 provides an overview of the study participants' demographics by camp year. The students were between the ages of nine and 12 with about two-thirds being male. In terms of race, 55% were white and 25% identified as American Indian or Alaska Native. The remaining students identified as Asian, Hispanic or preferred not to respond. One student was present for camp in both summers, and no other student had participated in this camp before.

Table 1

Demographics of Camp Participants

	Year 1[a] n (%)	Year 2[b] n (%)
Gender		
Male	16 (70%)	14 (67%)
Female	7 (30%)	7 (33%)
Race/Ethnicity		
White	10 (43%)	13 (62%)
American Indian/Native Alaskan	8 (35%)	3 (14%)
Asian	2 (9%)	4 (19%)
Hispanic/Latinx	1 (4%)	0 (0%)
No response	2 (9%)	1 (5%)

[a]Year 1: *n* = 23
[b]Year 2: *n* = 21

Instructional Context

The camps were five days in length and held on a large university campus in a Midwestern state, where local elementary students were invited to participate in learning about engineering design. Each day of the camp ran for 3.5 hours, with snacks and a break provided in the middle of each day. The camp has been operating at this university since 2016 and is facilitated by faculty and graduate students in the mathematics and science education program. The goals of the engineering camp were to (1) introduce students in grades 4-6 to the engineering design process and how it can be used in the context of solving a problem, (2) help students develop an understanding of the work of an engineer, and (3) increase engineering career awareness by presenting a variety of engineering fields and careers associated with those fields.

On the first day of camp, the students were divided into teams of 3-4, introduced to the camp staff, and completed pretests. The camp director then provided an overview of engineering design and how the campers would use it throughout the week. The remainder of the week was spent completing engineering design tasks, touring engineering facilities on campus, learning about engineering careers, and talking with engineering faculty about their various fields of study. Camp instructors used a variety of strategies to ensure all learners were actively engaged and able to access the material, including but not limited to, small group work, hands-on modeling of abstract concepts, using probing questions to elicit student thinking and facilitate meaning making, and exposure to gender and ethnically diverse professional engineers. At the end of the week, campers completed posttests and the campers' families were invited to come to a showcase event, where the projects from the week were displayed and campers shared their experiences at the camp with invited guests. Table 2 provides an overview of each day's schedule.

Table 2

Camp Schedule Overview

Day 1	Days 2-4	Day 5
• Pretests • Introduction to engineering design • Design challenge • Exit ticket • Take-home challenge	• Engineering career highlight activity • Design challenge • Guest speaker or facility tour • Design challenge • Exit ticket • Take-home challenge	• Engineering career highlight activity • Design challenge • Posttests • Family showcase

The possible selves that children view as achievable are influenced by their personal exposure to careers and role models. With this in mind, we structured each day to highlight specific engineering fields and careers through in-person visits from engineering faculty and videos that showcased engineers at work. Camp staff solicited engineering faculty volunteers who were both interested in speaking with elementary students and whose schedules allowed them to visit camp in person. This allowed campers to see, hear, and pose questions to both male and female engineers in fields such as mechanical, aerospace, chemical, civil, architectural, biomedical, environmental, agricultural, and electrical engineering. The design challenges for the camp were selected with several criteria in mind. First, the developmental appropriateness of the lesson was considered to ensure elementary friendly activities were chosen. Second, chosen activities represented good principles of engineering design as laid out in *A Framework for K-12 Science Education* (National Research Council, 2012). Many of these tasks were taken or adapted from sources such as TeachEngineering (http://teachengineering.org) and Engineering is Elementary® (Museum of Science Boston, 2003). Third, the types of design challenges were selected to align with the career fields of the visiting engineers. Different design challenges were used at each camp in order to keep the camp engaging for students who might attend multiple years.

Measures

Researchers used several instruments to assess the impact of the camp on students' understanding of the work of an engineer, potential engineering career paths, the engineering design process, and attitudes towards engineering. Details about each instrument are provided below.

What is Engineering? (WiE)

This instrument, developed by Cunningham (2005), explores student conceptions about the work of an engineer. It was developed to allow researchers to gain insight into the depth of knowledge students have about engineering. This instrument consists of sixteen images and descriptors along with one free response question. Image descriptors include improve machines, construct buildings, arrange flowers, and read about inventions. Students are asked to identify the items that represent the work that engineers engage in, and then describe an engineer in words. The What is Engineering? instrument has been shown to have good internal consistency with a Cronbach's α of 0.881 (Cohen, 1988).

Engineering Design Process Questionnaire (EDPQ)

The EDPQ instrument explores student understanding of the engineering design process and the work of an engineer. It includes three open-ended questions: (1) describe the work of an engineer, (2) list as many different types of engineers as you can and describe the jobs that each might have, and (3) describe the engineering design process. There is also a Likert-style question where students rate their understanding of the engineering design process, ranging from not knowing at all to understanding very well. For this study, only the first two questions were analyzed. This instrument was developed by the researchers for the purposes of the camp and to address the research questions for this study. To ensure that the questions were appropriate for upper elementary school students, the researchers determined their Flesch-Kinkade readability score, which indicated a 5th grade reading level. The camp instructor read questions aloud for those participants who required additional assistance.

Engineering Interest and Attitudes (EIA)

The EIA instrument was developed by Lachappelle and Brennan (2018) to determine the extent to which students develop interest in engineering and what their attitudes are toward engineering upon encountering engineering design. This instrument consists of a twenty-four item five-point Likert scale in which students rate their agreement to each item from strongly disagree to strongly agree. Items are grouped into subcategories to evaluate engineering attitudes among students according to the value to me, enjoyment, value to society, school engineering, aspirations, and gender bias. This study was looking at the effect of the camp on students' understanding of the work of engineers, awareness of engineering careers, and attitudes toward engineering. Based on the research purpose and the nature of the intervention, the researchers chose to eliminate the subcategories for school engineering and gender bias. The instrument, as designed, asks for students to assess themselves in their past and in the present. The instrument was modified for this camp to record only their current attitudes and interests in the pretest and posttest. To validate the EIA, Lachappelle and Brenna (2018) established the validity of the instrument using both content validity via an expert panel and through both exploratory and confirmatory factor analysis.

Data Collection and Analysis

Camp facilitators gave each instrument as a pretest to the campers on the first day of camp, then retested them on the last day of camp. Each student completed a demographic questionnaire, followed by the WiE, the EIA, and the EDPQ. Quantitative data was transferred to SPSS for analysis. The first author scored the first two instruments for each student by indicating whether each item was correctly or incorrectly selected and found the total number of correct selections for each student.

The pre-post data did not meet the assumption of normality; therefore the data was analyzed using the Wilcoxon Signed-Ranks test. The EIA was divided into subscales by averaging each of the individual item responses that make up each subscale. These averages, which also did not meet the assumption of normality, were run using the Wilcoxon Signed-Ranks test.

The open-ended responses from the EDPQ and WiE instruments were transcribed into Excel and analyzed independently by the first two authors. Instead of establishing an a priori coding system prior to looking at the responses, the authors used the phrases given by the participants to establish the coding (Saldaña, 2015). The responses to the first question were read twice to look for keywords and responses that the participants used to describe the work of an engineer, such as improve, fix, and design. Researchers then developed codes from the key words and phrases, lumping those with the same meaning and context. The frequencies of these codes were then measured for both pre and posttest. Once complete, the researchers met to discuss their findings and compare notes. During this meeting, any discrepancies in the way the phrases were coded were discussed until a consensus was reached. Once the researchers agreed on the coding, they ensured that frequencies for each code matched for analysis. Researchers then looked at each participants' pretest and posttest response to compare the two and search for meaningful changes in the responses.

The engineering type questions were marked and labeled for each type of engineering that was identified by the student, classifying it first as accurate or inaccurate, then within a subcategory of the type of engineering. Accurate responses correctly identified engineering types, such as mechanical, civil, and chemical. Inaccurate responses included descriptions of actions like "repair cars" or jobs that are not engineers like "plumber". The responses were counted and compared graphically, then analyzed using a Wilcoxon Signed-Ranks test.

Results

What is Engineering? Instrument

Figure 1 displays the results of the WiE instrument, ordered from largest decrease to largest increase. The items "Design Ways to Clean Water" and "Work as a Team" had the largest increase, while "Improve Machines" and "Design Things" remained the most selected items on the posttest. Table 3 displays the results of the Wilcoxon Signed-ranks test, which indicated that student conceptions of engineering before camp (*Mdn* = 10) were not significantly different from their conceptions after camp (*Mdn* = 11), $Z = -1.799$, $p = .072$. After discussion between the authors about the reason for the lack of a significant increase in scores and an examination of the data, it was determined that many students selected the item stating that "engineers teach children" in the posttest. During both weeks of camp, engineers came to speak to the students about their discipline, and the authors found it likely that students associated this as part of the work of an engineer. This item was subsequently removed from the data set and the test was run again. Without the teaching item included, the test indicated a significant difference between the pretest (*Mdn* = 9) and posttest (*Mdn* = 10), $Z = -2.324$, $p = .02$. The effect size ($r = .35$) for this analysis was found to be small according to Cohen's (1988) convention.

Engineering Design Process Questionnaire

The EDPQ instrument included a question that asked students to describe the work of an engineer, and the WiE instrument asked participants to complete the following prompt: "An engineer is a person who…". These questions were very similar and were given within a few minutes of each other, but the responses were not always the same. For example, in the pretests participant 45 described an engineer as a person who "solves problems", but described the work of an engineer as "fixing things (electronics, etc.)". Additionally, in the posttests, participant 41 stated that an engineer "makes the world a better place", but described the work of an engineer as "buildings, vehicles, chemical, farms, human body". Overall, approximately 40% of the participants provided answers that were different on the two questions.

Figure 1

What is Engineering? Pretest/Posttest Responses

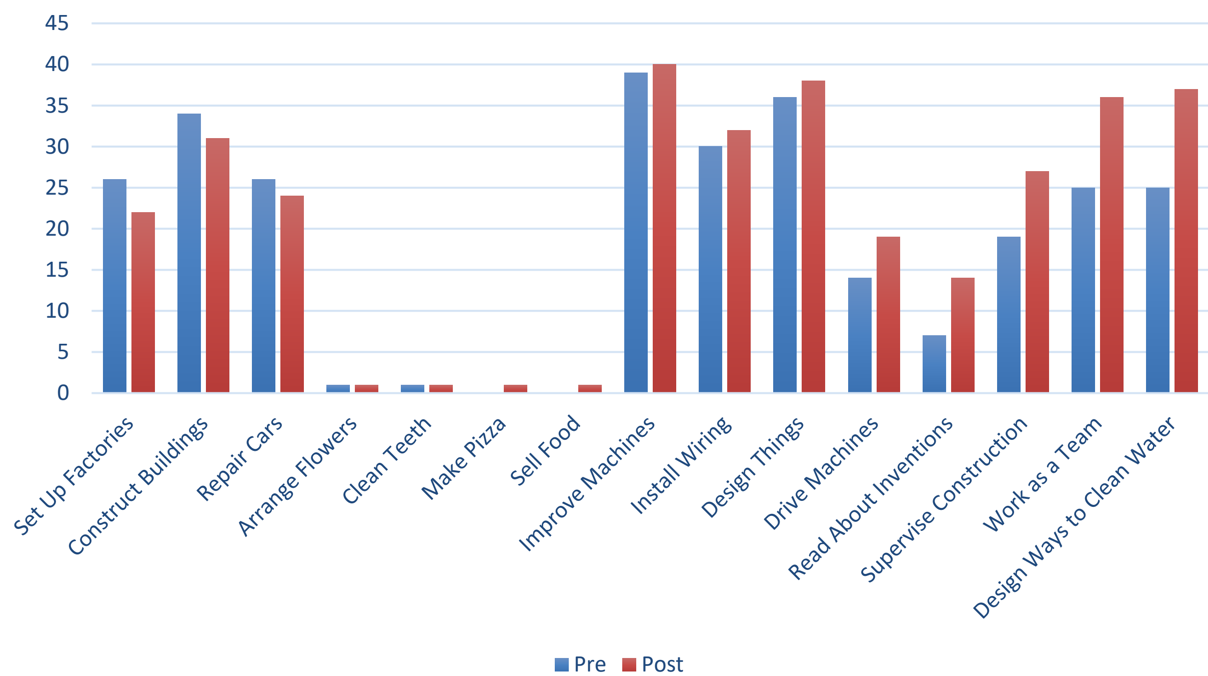


Table 3

What is Engineering? Pretest/Posttest Results

	Pretest			Posttest					
Subscale	Min	Max	Mdn	Min	Max	Mdn	*Z*	*p*	*r*
What is Engineering?	6	14	10	8	16	11	-1.799	.072	.27
Modified What is Engineering?	6	13	9	7	15	10	-2.324	.020*	.35

*Indicates significance at p < .05

The responses were compiled from both instruments, and the responses varied among the participants. The most common responses on the pretest indicated that engineers design (28 instances), build (27 instances), and repair or fix (17 responses). Eleven participants left their response blank or stated that they did not know. All other responses were recorded 10 or fewer times. On the posttest, the top two responses remained prevalent, with design occurring 24 times and build occurring 17 times. However, three categories increased by a large margin from pretest to posttest. "Problem solving in engineering" increased from 10 responses on the pretest to 23 on the posttest, making it the second most-used phrase. "Helping" increased from 3 to 16, and "improve" increased from 10 to

16. Furthermore, the number of responses from students that said they did not know dropped from 11 on the pretest to 6 on the posttest.

Examination of individual responses before and after the camp revealed few major differences for students, except for the addition of clarifying or purpose statements. For example, participant 13 stated in the pretest that "engineers usually design and fix things", while their posttest response stated that "engineers usually try to make society better by making new things and improving old things". Participant 9 began with the idea that engineers "improve and plan and build stuff", but after the camp stated that "they help improve our lives".

The second question on the EDPQ asked students to name as many types of engineers as they could. Figure 2 displays the results, which indicated that the number of correct responses increased from 30 to 133, the number of incorrect responses decreased from 26 to 4, and the number of students who did not respond decreased from 12 to 7. To ensure that the increase in number of correct responses was not due only to one or two students who were able to name a large number of engineers, the responses were analyzed for each student, and categorized into responses that gave zero correct responses, one to three correct responses, and four or more correct responses. The results, shown in Figure 3, indicate that the number of students naming zero engineers dropped from 27 to 6, the number naming one to three engineers remained the same, and the number naming four or more engineers increased from 1 to 21.

Finally, researchers analyzed the change in total number of correct responses by running a Wilcoxon Signed-Rank test, which indicated a significant increase in number of engineers the students could name, $Z = -5.040$, $p < .001$, and revealed a medium effect size ($r = .56$) which indicates that the camp experience was effective at increasing students' awareness of an existence of different engineering disciplines.

Figure 2

Total Number of Correct Types of Engineers in Participants' Responses

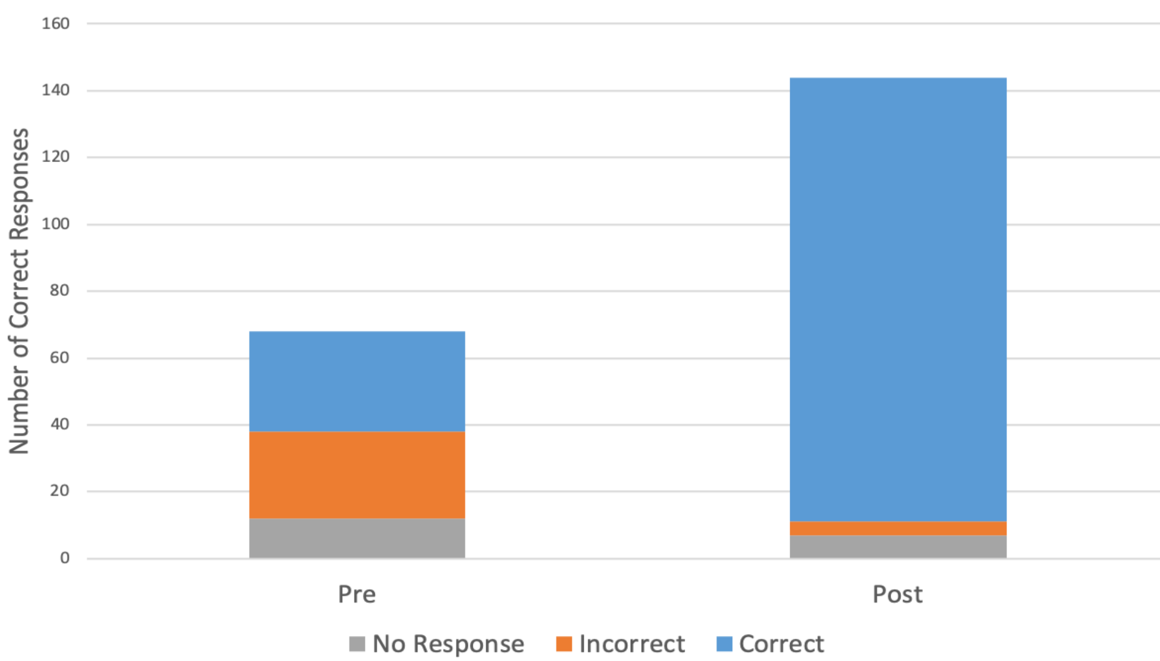
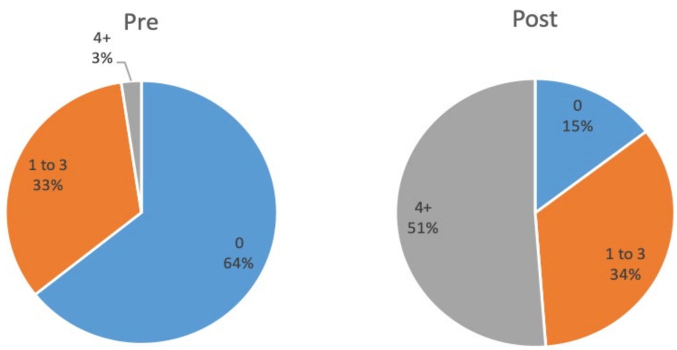


Figure 3

Number of Correct Responses Given by Individual Participants



Engineering Interests and Attitudes Scale

Table 4 presents the results of the Wilcoxon Signed-Rank test for each of the EIA subscales. The EIA instrument indicated that participants' attitudes in each of the subscales either increased or remained the same, however only two categories were significantly different from pretest to posttest. The test provided this difference for the value of engineering to society (Z = -3.782, p < .001) and aspirations toward engineering (Z = -2.284, p < .022). The effect size for the value of engineering to society (r = .59) suggests a medium effect, and aspirations toward engineering (r = .36) suggests a small effect. The value of engineering to me subcategory, while not significant at p < .05, also revealed a small effect size (r = .30). According to the convention developed by Cohen (1988), these effect sizes suggest that the camp was somewhat effective at improving students' attitudes toward engineering in these subcategories. However, caution should be used when interpreting the meaning of effect sizes because these general categories developed by Cohen may be interpreted differently according to the context in which they are used.

Table 4

Engineering Interests and Attitudes

	Pretest			Posttest					
Subscale	Min	Max	Mdn	Min	Max	Mdn	Z	p	r
Value of Engineering to Me	2.0	5.0	4.0	2.0	5.0	4.5	-1.919	.055	.30
Value of Engineering to Society	2.6	5.0	3.8	1.0	5.0	4.8	-3.782	<.001**	.59
Enjoyment of Engineering	1.0	5.0	4.0	1.0	5.0	4.0	-1.287	.198	.20
Aspirations Toward Engineering	1.0	5.0	3.9	1.0	5.0	4.5	-2.284	.022*	.36

*Indicates significance at p < .05
**Indicates significance at p < .001

Discussion

The analysis of the WiE instrument suggested that camp participants initially believed that engineers engaged in tasks such as repairing cars and constructing buildings, which is in line with prior work on understanding of engineers (Capobianco et al., 2017; Capobianco et al., 2011; Newley et al., 2017). After analysis, the results from the pretest to posttest were not significant. However, the removal of the item regarding teaching did make the test significant, and the effect size increased from $r = .27$ to $r = .35$. While this effect size is considered small according to Cohen's convention, the growth in understanding of the work of an engineer is consistent with other engineering interventions (Farland-Smith & Tiarani, 2016; Hammack et al., 2015). However, seeing that one aspect of the camp so prominently affected the results of the posttest, we feel that it is necessary to consider the importance of the context of an intervention in determining the results. These results indicate that the way in which curriculum is presented can have a substantial impact on the way students view or understand a particular topic. Specific aspects of the curriculum that are either included or left out may play a meaningful role in participants developing an understanding of what engineers do, and should be an important consideration for the design of future experiences.

Another consideration to be made based on the results of this study is the need for multiple assessment methods in research. There were similar questions about the work of engineers on two separate instruments, and 40% of participants responded with different answers. While for some, these differing responses may represent the variety of concepts they have about engineers, it also demonstrates the fragility of these participants' understanding of engineering. By using two measures, it was possible for the researchers to gain insight into the variety of ideas that participants had, while also seeing how their understanding lacked depth and stability.

Nevertheless, certain shifts in the responses did indicate that the context, message, and activities present in the camp had an impact on participants. The biggest increases in students' responses to describing engineers and their work involved engineers helping, improving, and finding solutions. Many of the participants specifically included these aspects of the work of engineers into their responses alongside other practical activities such as designing and working as a team. Typically, the engineers that visited in person or were displayed on video talked about the impact of their work on people's lives. Additionally, many of the challenges were rooted in real-world problems and described how engineers could work to solve the problems at hand. This change in participant responses represents a deeper understanding of what engineers do and why they do it. The participants understand that there is a purpose to the work of engineers. Such changes suggest that the messages from camp speakers, videos, and challenge scenarios may have influenced students to see engineering as helpful to the world around them.

Results from the career awareness section of the EDPQ were analyzed in two different ways to determine participants' ability to name different types of engineers. The first analysis demonstrated that the total number of correct responses increased dramatically, and the number of incorrect responses and no responses decreased. This suggests that participants had a greater awareness of types of engineers after participating in camp activities, learning about engineers, and meeting engineers. Gathering the compilation of individual responses showed that multiple participants increased the numbers of engineering careers they could list. Furthermore, the most commonly named types of engineers were those that visited the camp to do a presentation.

These results suggest that participation in an engineering camp that focuses on career awareness can increase the number of possible career options in engineering that a student is able to consider. Studies of interest development and career choice in STEM suggest that exposure to available careers and engagement with the work of those careers can increase students' interest in pursuing those careers (Mohr-Schroeder et al., 2014; Wai et al., 2010; Yilmaz et al., 2010). Additionally, students who are exposed to more examples of engineers and their work at a young age may be more likely to view these options as possible future selves. This supports students in making the choices that might set them toward a career path in engineering because they envision that path as a possibility for themselves (Oyserman & Markus, 1990).

Attitudes toward engineering can encompass a variety of categories and therefore can be difficult to define. Lachapelle and Brennan (2018) discuss the development of attitudes toward engineering as the appraisal and judgement of "engineers, engineering as a profession, and learning experiences in engineering" (p. 222). The results from this study demonstrate that the engineering camp significantly increased students' perceptions of the value of engineering to society and aspirations toward engineering. First, this suggests that engaging in the work of engineers during a camp with projects focused on real-world scenarios can improve participants' attitudes about the role that engineers have in improving the world around us. Ing, Aschbacher, and Tsai (2014) demonstrated that seeing engineers making people's lives better improved interest in engineering careers, especially among females. Secondly, there was an increase in participants' aspirations toward engineering, which suggests that experience with engineers and engineering design may enhance participants' belief in their potential future as engineers. This supports the view that availability of role models and career exposure can open the door for young people to develop possible selves as engineers (Oyserman et al., 1995).

It should be noted that while the subscale for value of engineering to the individual was not significant, it was nearing significance (p = .055) and demonstrated a small effect size (r = .30). This is important because participants came in with generally strong positive attitudes toward engineering already. The average response was 3.9 out of 5.0 at the beginning of camp. While this alludes to the self-selected nature of the camp participants, the increase in multiple subscales indicates that the camp did have a positive effect on students' interests and attitudes toward engineering.

Limitations and Suggestions for Future Research

It is important to note the limitations associated with this study that impact the generalizability of the findings. First, camp participation was voluntary with either students self-selecting into the program and/or students' parents choosing to enroll them in the camp. Second, only a limited number of spots were available for participation each year due to resource limitations (e.g. facility space, personnel availability, cost of materials), and all participants hailed from the same midwestern community, limiting the geographic diversity of the sample. While we pooled data from two years of programming, the overall sample size was still relatively low.

Additionally, the data collected from the participants demonstrates the limited ideas that they were able to convey on paper instruments. While this data does provide worthwhile information for study, it would be beneficial to talk to students as well to gain a deeper understanding of their thinking. Future studies should include follow-up interviews with students to expand on this limited data, or interviews with parents to discuss the conversations that their children brought home during or after camp.

Despite the limitations, the study findings add to the knowledge base in engineering education and point to important areas for future research. The production of positive results indicates that the camp has many of the curricular characteristics that are beneficial for improving students' understanding, awareness, and attitudes. However, future camps will need to continue to improve on these results by continuing to emphasize career awareness and the work of an engineer. Because the camp did not significantly improve students' enjoyment of engineering, and the increase in understanding of the work of an engineer was small, future camps can also work to improve on each of these features. Finally, while the findings from this study indicate a positive result, there is little known about what causes students to move from their initial understandings and attitudes to their final positions. Future studies should focus on these incremental changes and how students interact with engineering design while they are working on hands-on projects.

Conclusion and Implications

This work adds to the literature on engineering education in two meaningful ways. First, the study illuminates how easily standard instruments can be influenced by the context of an intervention. In the current case, the WiE instrument was not able to discern changes in students' pre to post understanding of engineering due to the inclusion of the item "engineers teach children." When this item was removed from analysis, researchers were able to detect significant pre to post differences, indicating the need for researchers to carefully consider how instrument items might limit detection of gains under certain conditions. Furthermore, instruments may not always give an accurate depiction of a person's thinking or be able to detect changes, as evidenced by the lack of consistency in participant responses to similar questions on the WiE and EDPQ instruments.

Second, this work adds to the literature by providing evidence that an informal learning opportunity focused on engineering career awareness can enhance elementary-aged students' awareness of different disciplines of engineering and their aspirations towards engineering. The need for students who pursue an engineering career path is continuing to grow (World Economic Forum, 2017), and this need will only be met as students develop interest in engineering and believe that they have a possibility of becoming an engineer (possible self) in the future (Oyserman & Markus, 1990). While interest can be developed at any time, students who develop an interest in physical science or engineering careers by the 8th grade are 3.4 times more likely to pursue a career in those fields than those who are not interested at that time (Tai et al., 2006). Informal learning experiences such as camps have demonstrated promise in developing these interests in young students, and the engineering camp in this study adds to those results. The camp improved students' understanding of the work of an engineer, and most participants left camp with a greater awareness of the types of engineers and engineering careers that are available to them, possibly enhancing their ability to see a possible future self of engineer. Furthermore, participants' attitudes about the value of engineering and aspirations toward engineering became more positive through the camp. These findings suggest that a learning experience that incorporates hands-on activities that resemble the work of an engineer, a focus on types of engineering careers, and interaction with engineers can provide some of the pieces necessary to prepare a workforce that will meet the needs of our future society.

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