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"IT MAKES ME WANNA GO OUT AND HELP PEOPLE": ENHANCING AFRICAN AMERICAN YOUTH'S PERCEPTIONS OF ENGINEERING

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Researchers theorize that identification with a career field is achieved when there is alignment between student values and their perceptions of the values a career field meets. Stereotypically, engineering is perceived to align with status values, such as high pay, but the reality is that engineering is a collaborative enterprise that solves critical social challenges. To portray a more accurate view of the field, we designed a summer camp experience around the Grand Challenges for Engineering to highlight the impacts of engineering on society and our everyday lives. We evaluated the effects of this camp in reframing engineering as an altruistic career for grade 8–10 African American students who came from a low-income, urban community. Interviews and surveys assessed the impact of the camp on students' self-efficacy and interest in engineering. We used qualitative coding in our interview data and a combination of nonparametric and intensive longitudinal models for our quantitative data. Analyses indicated that students' engineering self-efficacy increased. Intensive sampling of attitudes suggested that camp activities that were rated higher on "helping people" received higher ratings of interest and self-efficacy. Through the interviews, we found that the camp led to meaningful changes in students' appreciation of engineering and, in some cases, new interests in pursuing engineering as a career. Framing engineering as an altruistic career path led to meaningful changes in students' definitions of engineering and their connection of engineering to their career interests. Future research should explore extensions of this work to other populations of students.

KEY WORDS: *K–12 outreach programs, engineering education, high school, Black youth, program evaluation, identity formation, career values*

1. INTRODUCTION

Researchers theorize that students will be more interested in a career field when there is alignment or *congruity* between the student's values and their perceptions of the values a career field meets (Diekman and Steinberg, 2013; Merolla and Serpe, 2013). Stereotypically, engineering is seen as affording only the pursuit of status values, such as high pay, independence, or respect from others, which may be inconsistent with the values of some students, especially women and some minorities underrepresented in the field (Allen et al., 2015; Becker, 2010; Capobianco et al., 2011; Diekman et al., 2011; Estrada et al., 2016; Wade, 2012). However, the National Academy of Engineering (NAE), among others, asserts that common beliefs about engineering reflect a misunderstanding of the field and is making sustained efforts to portray the field as having a profound impact on society and as one that can meet communal or altruistic career goals (NAE, 2008, 2013, 2015). The goal of this research was to develop a summer camp experience around a more accurate, *altruistic* framing of engineering and explore the impact of the camp on the attitudes and perceptions of engineering among 8th–10th grade students who came from an urban, predominantly Black and low-income community. The design of the camp was tailored based on prior research around the values and interests of students in this community.

Career values have been defined in a number of ways (Brown et al., 2015b; Prediger, 1982; Su et al., 2009; Su and Rounds, 2015), but a consistent distinction has been made between values that are self-focused, including agentic or individualistic values—such as wanting high pay, independence, or respect—compared to values that are other-focused or communal, which include wanting to help others, to have close connections, or to work with others. In terms of motivation for STEM careers, Brown et al. (2015b) distinguished that the facet of "helping others" or altruistic values was especially motivating compared to other communal values focused on spending time with or wanting to work with others. Thus, we focus on the distinction between individualistic and altruistic values in this study.

A substantial body of literature indicates that women are more likely to prefer altruistic or communal careers (Konrad et al., 2000; Su and Rounds, 2015), and researchers have explored whether these gender differences in career preferences and values can help explain existing gender differences in the choice of STEM college majors (e.g., Belanger et al., 2020; Brown et al., 2015b; Diekman et al., 2010). Other groups who have been underrepresented in engineering careers may also be more motivated by values or interests around helping others. At a cultural level, researchers have found that African American or Black culture strongly favors careers that give back to the community, consistent with communal or altruistic goals (Boykin et al., 1997; Jagers and Mock, 1995). This is also reflected in individuals' values, where Black adults have been shown to favor social-focused careers compared to a sample of white adults, although gender, race, and even education level also have complex interactions when it comes to career values (Jones et al., 2020; Kashefi, 2011). Allen et al. (2015) found that first-generation college students were more intrinsically motivated to pursue a science career when they believed it had strong communal affordances. As a result of this line of empirical work, Estrada et al.'s (2016) call to action highlights the importance of igniting the motivation of students based on their values and career goals to increase the persistence of underrepresented groups in STEM career pathways.

1.2 Goal Congruity Theory and Interventions

The *goal congruity theory* predicts that students will be more interested in a career field if they perceive an alignment between their own career values or goals and the *affordances* of a career field (i.e., the values a field allows individuals to reach). Goal congruity is aligned with the *expectancy-value theory* of human motivation (Wigfield and Eccles, 2000), which states that motivation for learning is a function of the value that a student holds (task value) and their expectations for success (that is, self-efficacy). Goal congruity interventions help students recognize alignments of their values to a learning task, thus increasing the task value and, ultimately, their motivation. This prediction is also consistent with career-level decisions through the Social Cognitive Career Theory (SCCT) (Lent et al., 1994, 2000), which also specifies that students' experiences shape their career goals through impacting their self-efficacy and outcome expectations, which is the belief that *valued* results will be achieved.

Interventions have been developed to explore how these preferences can be leveraged to engage more girls and women in STEM careers through framing fields in terms of the communal value affordances they offer. For example, Brown et al. (2015b) experimentally manipulated the framing of a biomedical research study to emphasize the impact the research would have from an agentic vs. communal framing. They found that the influence of communal framing was positive and replicated in several situations. Both experimental and correlational studies have found that perceptions of communal affordances are associated with greater interest in STEM fields with a particular focus on these results for women and girls (Brown et al., 2015a,b; Fuesting and Diekman, 2017; Klotz et al., 2014).

1.3 Existing STEM Programming for Black Youth

Most research on goal congruity has focused on women and girls without particular consideration to socioeconomic status or race. However, interventions to engage these groups of students in STEM careers have a long history. Minority engineering programs (MEPs) as well as national organizations, including the National Society of Black Engineers (NSBE), have demonstrated their longstanding commitment to increasing the presence of underrepresented minority students in engineering, including K–12 outreach programs (Buckley et al., 2019). Jeffers et al. (2004) similarly highlighted that diversifying the engineering workforce is an important focus of many K–12 outreach programs.

At the undergraduate level, many institutions invest in MEPs in order to provide underrepresented minority undergraduate engineering students financial, social, and academic support (Buckley et al., 2019). Nealy (2018) suggested these programs provide an affirming space for students to develop stronger professional identities within their STEM field (see also Nealy and Orgill, 2019; Simmons et al., 2014; White, 2017). Notably, Nealy (2018) found that each MEP program studied engaged students in K–12 outreach activities. These aspects of the programs had profound positive impacts for the undergraduate students themselves because their identity as a scientist or engineer was made prominent in their role modeling and mentoring activities.

Precollege programs, including NSBE's precollege initiative program, are intended to encourage K–12 students to develop interest and skills in math and science through hands-on activities (NSBE, 2016). In analyzing summer bridge programs, Reid et al. (2016) outlined the important resources to college success included not just academic skills but also self-confidence, knowledge about the college environment, and access to college community, including peers and faculty. Indeed, evaluation of these kinds of programs, tailored specifically to the needs of Black youth or other historically marginalized groups, find that their impact on student self-concept or identity as well as attitudes towards STEM form important positive outcomes of the programs (Bayer Corporation, 2010; Strayhorn, 2011; Zhou, 2020).

For the field of engineering in particular, Jeffers et al. (2004) noted that many students lack an understanding of what engineering is, either due to a lack of exposure to the field or, possibly, due to the misconceptions of the adults and educators in their lives (see the following section, Misconceptions of Engineering). By exposing students to hands-on activities through inquiry-based learning environments as well as having them engage with role models in engineering fields, precollege engineering outreach programs have the capability of helping students gain valuable knowledge and understanding of these fields (Jeffers et al., 2004). As a result, interest in, exposure to, and early understanding of engineering fields at the secondary level can excite and inspire students to pursue these fields at the college level.

Based on the career values literature suggesting that Black youth are more likely to have altruistic or community-focused career values as well as the literature on goal congruency for girls and women, we sought to explore a goal-congruency intervention designed specifically for a population of Black youth coming from an urban, low-income area. We hypothesized that framing engineering as an altruistic or community-focused career pathway might be a useful strategy that could be easily adopted by these existing MEPs and K–12 educational outreach programs.

1.4 Misconceptions of Engineering

Much of the work on communal framing focuses on STEM in general or specific domains of science, such as biomedical sciences, which have obvious connections to helping others (e.g., Allen et al., 2015; Thoman et al., 2014). The field of engineering has not received as much direct attention, possibly because it is even more misunderstood as only meeting individualistic values. Engineering fields have historically been perceived only to afford the pursuit of individualistic and not communal goals (Capobianco et al., 2011; Diekman et al., 2010; Stevens et al., 2008).

Researchers have demonstrated that the public widely holds misconceptions of engineering (Sullivan, 2006). In their analysis of teachers' responses to the Draw an Engineer Test (DAET) after a training program, Lambert et al. (2007) discovered that teachers were likely to describe that engineers design or build/construct things, but they rarely mentioned that the products of engineering are all around us or impact our everyday lives. Even less common were details about how engineers work collaboratively or the importance of creativity to their work. In their quantitative survey, Cunningham et al. (2006) reported that teachers were more likely to believe engineers actually construct buildings themselves and drive machinery rather than planning and supervising these tasks. Given this lack of awareness of the field and the importance of teachers as an early source of career information, it is no wonder that Capobianco et al. (2011) found many elementary-grade students depicted engineers as mechanics and laborers working directly on mechanical devices, including vehicles and engines. These limited ideas among adults in their lives may leave students unaware of the breadth and importance of engineering in our everyday lives—knowledge that might otherwise inspire them to engage in this career field.

1.5 Grand Challenges for Engineering

Professional organizations have raised the alarm that the lack of public awareness of the role of engineering and value to society leads to fewer students pursuing the field as well as weaker investment in the field (Chan and Fishbein, 2009; Vest, 2010). In response to this call, the NAE (2008, 2013) introduced a series of marketing campaigns to counter these common misperceptions of engineering in order to increase the number and diversity of students entering engineering career fields. One of their campaigns to change perceptions is the *Grand Challenges for Engineering* (NAE, 2008), fourteen challenges facing modern society that reinforce the message that engineers use their creative problem-solving skills to improve our world and shape the future (NAE, 2013). See Table 1 for a list of the Grand Challenges. Each of these challenges impact people around the world, and using these challenges as framing for engineering projects and lessons can engage students who are interested in having a career that helps others or solves problems they observe in their everyday life.

Most of the work evaluating the impact of the Grand Challenges has focused on undergraduate engineering majors and their perceptions of lessons based on Grand Challenges (Corneal, 2014; Litzler and Lorah, 2013). For example, Corneal (2014) found that students responded positively to a group project organized around their choice of a Grand Challenge. Our own work (Davis et al., 2016) looked at the impacts of Grand Challenges as part of a freshman engineering course and showed positive gains in their knowledge on module-specific content tests. This study extends the literature by exploring the impacts of Grand Challenges on high-school-aged students who are not already committed to engineering college programs.

TABLE 1: National Academy of Engineering, "Grand Challenges for Engineering"

Challenge
Make solar energy economical
Provide energy from fusion
Develop carbon sequestration methods
Manage the nitrogen cycle
Provide access to clean water
Restore and improve urban infrastructure
Advance health informatics
Engineer better medicines
Reverse-engineer the brain
Prevent nuclear terror
Secure cyberspace
Enhance virtual reality
Advance personalized learning
Engineer the tools of scientific discovery

1.6 The Current Study and Intervention

Goal congruity theory and SCCT predict that students will be motivated to pursue a career field if they feel they are likely to obtain valued outcomes from a learning experience. Therefore, we were interested in changes to students' perceptions of the value affordances of engineering, their self-efficacy, and their interest in engineering topics or a career.

Much of the previous work on congruity theory has focused on women and college students, and there has been limited research on educational interventions to leverage goal congruity to broaden participation in engineering. The objective of this research was to understand how framing engineering as an altruistic profession affects the development of career interests of low-SES, African American 8th–10th grade students from an urban area in a predominantly rural Southern state. Our research questions were as follows:

1. How did the camp experience overall influence students' interest, efficacy, and perceptions for engineering as a career field?
2. How did individual activities throughout the camp influence students' interest, efficacy, and perceptions of engineering as an *altruistic* career?
3. How did the camp experience influence students' definitions or perceptions of engineering as a career field? Did the camp experience help students identify new areas of interest in engineering?
4. Were changes in students' definitions or perceptions of engineering related to altruistic or communal perceptions of engineering?

1.7 The Intervention

To provide the framing of altruistic engineering, a week-long summer camp was organized around the Grand Challenges for Engineering to demonstrate how the field of engineering addresses important societal challenges. The camp was developed through the Design-Based Research Process (Easterday et al., 2014), which is an iterative process of **conceive-build-test** that is informed by planning stages for **focusing** the problem, **understanding** the context, and **defining** the solution. In other words, we conducted an extensive exploration process with our target population of students prior to designing the camp to meet their needs. We then evaluated the initial camp to improve future designs.

The extensive exploration phases for focusing, understanding, and defining the solution took place in partnership with Alabama STEM Education (ASE), a nonprofit organization that has served the target population of students since 2016. ASE offers a Saturday Academy program that consists of weekly themes around STEM domains, including mechanical engineering, aerospace engineering, biomedical research, and other engaging topics. The learning opportunities include hands-on activities, guest speakers from local universities, and museum visits such as to the local aviation museum. Participants of the program consist of low-income students who are underrepresented in STEM disciplines and live in Bessemer or Birmingham, Alabama.

Collaboration with ASE, including regular observation of the program, participating in educational activities, and conducting an evaluation of the impacts of the ASE program on students, allowed us to familiarize ourselves with this population of students, gather information on their career interests and values, and to explore possibilities for designing our summer camp program. Although none of the students in the Saturday Academy participated in the summer camp (because we wanted to avoid serving students already connected to STEM), we learned a great deal about the topics and types of activities that were most engaging for this population of students and confirmed that helping others and serving the community was a prominent value for most students.

In planning the summer camp, the leadership team included chemical engineering, materials engineering, and computer science and software engineering (CSSE) faculty who were also involved in the collaboration with ASE. We titled the camp Tomorrow's Community Innovators (TCI) and sought to minimize the focus on engineering during recruiting by highlighting that we were recruiting students interested in solving problems in their community. The recruitment information stated:

> *Do you want to make life better for your family and community? Do you have ideas for how to help your community right now? Do you want skills for the future? Then this is the program for you! We will learn about new inventions and ideas that can make lives better for the people around us and create solutions that you can implement right now and in your future career.*

Most days of the camp had a specific engineering theme that incorporated the Grand Challenges for Engineering[5]: providing access to clean water (Tuesday), making solar energy economical (Wednesday), and restoring urban infrastructure (Thursday). We chose these three Grand Challenges to focus on based on our surveys of students in Bessemer, which confirmed that these Challenges were particularly interesting to these students.

To introduce the camp, the first day (Monday) began with an activity, "What's the Challenge?," which introduces the Grand Challenges to students in a way that aligns the list of social challenges to students' own observations of the world. The activity is essentially a series of group brainstorming exercises where students identify problems in the community, identify technological solutions, and then collectively list the most important problems they felt society needed to solve [see Lakin et al. (2021) for a detailed description]. On the afternoon of that first day, students learned the essentials of App Inventor and created a simple interface as a demonstration project (Bhattarai et al., 2021).

Each day's activities were related to a theme. Students spent mornings on hands-on laboratory activities and afternoons either using App Inventor (Pokress and Veiga, 2013) to build apps or programming robots in activities related to the daily theme. On Tuesday, the morning activity focused on the challenge of providing access to clean water and involved building a water filtration system to remove large particulates from contaminated water. Students then used filters with silver nanoparticles to further filter the water and test the quality of the filtered water using test strips and a multiday test of bacterial content with petri dish cultures. In the afternoon a CSSE graduate student demonstrated an app she had built where users could map the location of water leaks and contamination. Students then built a game in App Inventor to demonstrate water clean-up projects (specifically, collecting trash from the ocean).

On Wednesday, students tested commercial solar panels to learn about the impacts of direct and indirect sunlight on output. They then built their own solar panels to learn about the challenges of economical solar energy (Lakin et al., 2021). Correspondingly, in the afternoon they built an app that tracked solar panel efficiency. Students then created a simple app to convert energy data for record-keeping purposes (e.g., converting Fahrenheit to Celsius).

On Thursday, students learned about urban infrastructure by working as a team to gather information from community stakeholders (mentors acting in assigned roles such as town mayor or economic developer) and then planning a city block and using their limited budget to place necessary buildings and roads. This activity was developed from an outreach-focused lesson plan (Foresight Group, 2014). In the afternoon, a CSSE graduate student demonstrated a self-driving robot that used color sensors to detect a predetermined path indicated by color. After the demonstration students programmed the self-driving robot to avoid obstacles on a course.

In addition to the formal content, students participated in lunches with role models from industry, Engineers without Borders, and Auburn University's Black Student Union. They also participated in fun activities such as icebreakers, kickball, a football stadium tour, and a movie night. On Friday morning a graduation ceremony was held to celebrate the students' accomplishments and inform them about future opportunities to be involved with the project and institution.

2. METHODS

This study of a summer camp intervention was framed as a mixed-methods, explanatory case study with a focus on “rival explanations” in the style of traditional hypothesis testing (Yin, 2003). We were interested in understanding the students’ experience of this week-long program and triangulating data to find potential effects of the experience on students’ attitudes and beliefs about engineering as a career field and their own career path. Historically, evaluation of STEM education programs has relied on pre- and postcamp measures of attitudes, but this approach is limited because it only assesses change as predetermined by the scales (meaning that the breadth of change that is even detectable is set by the survey), tends to focus on broad changes in attitudes (interests in science or engineering generally), and is not diagnostic of which camp activities created more powerful or engaging experiences. Thus, we augmented a traditional pre- and postquantitative design with pre and postcamp interviews to explore changes in students’ perceptions and attitudes more effectively and authentically. We also introduced an intensive survey approach where students answered brief surveys after each camp activity, with the hope of detecting an interaction between activities that clearly demonstrated the prosocial effects of engineering and the interest or efficacy that students experienced for that specific kind of engineering task.

Our hypothesis was that framing engineering activities with Grand Challenges and an altruistic focus would enhance students’ perceptions of, interest in, or self-efficacy for engineering as a career field and that these changes would be related to perceptions of helping others. In other words, we thought that students would be more interested and confident if or when engineering was framed as a prosocial or altruistic field. We were also open to the possibility of no change in student perceptions or changes inconsistent with our hypotheses.

2.1 Participants and Context

To recruit participants, the research team worked in collaboration with the ASE nonprofit organization located in our target region of Bessemer, located in the outskirts of Birmingham, AL. Historically, Bessemer has been a center of industry along with the rest of metropolitan Birmingham, but like many former factory towns, it has experienced high rates of poverty and a substantial crime rate when industry left the area. According to 2019 statistics (U.S. Census Bureau, 2019), the city of Bessemer had around 26,000 residents, with 71% of residents reporting African American race. Only 14% of the adult population had a bachelor’s degree or more education, and 28% lived below the poverty level. Despite these dire statistics, these students have opportunities not available to their parents, because Alabama is seeing a return of industry through automotive manufacturing and other high-tech industries (Platzer and Harrison, 2009), including aerospace-related manufacturing particularly in the Huntsville area (about two hours north of Bessemer).

Our nonprofit partner has served this community since 2016, building strong local relationships. We worked with the staff to recruit students who would benefit from our summer camp program. The challenge was to attempt to attract students who were not already served by the organization's programs and thus might already have accurate views of engineering. Interested students completed an application form, which included an essay on what problems or challenges they saw in their community. We further screened participants based on the school they attended, giving preference to students attending public, traditional schools over those attending magnet schools with STEM programming and private schools known to offer high-quality education. In our interviews with students, we nevertheless ended up with many students already well connected to the STEM educational ecosystem, such as a student who was formerly enrolled in the selective Alabama School of Science & Mathematics but who was now in a public school due to his parents relocating. Another student was the daughter of a computer science professor at a local community college and told us she had a summer job as a STEM camp instructor! Despite these notable exceptions, most of our campers had little to no background in participating in STEM enrichment activities. The age, grade level, and gender distribution of our different subsets of participants are provided in Table 2.

2.1.1 Limitations to Data

This research study was carried out in the style of a program evaluation. While our research questions motivated the camp program, the project leadership and researchers were conscious that the primary goal was to create a powerful learning opportunity for the students, with data collection as a secondary concern. Therefore, data collection was designed to be as unobtrusive as possible. This led to our decision to only collect as many interviews as could be managed within planned camp activities. We also had some students who did not complete the full precamp surveys because they did not notice the double-sided pages while completing surveys (and socializing) in the communal area of their dorm.

TABLE 2: Interview participants

	Total participants	**Completed interviews**	**Completed survey**
Total	21	8	8
Male	7	4	2
Female	14	5	6
Rising grade			
8th	8	3	1
9th	6	4	3
10th	5	2	3
11th	2	0	1

2.2 Data Collection and Analysis

Our approach to this explanatory case study involved mixed methods that allowed us to triangulate findings across different analytical approaches. We used three main methods: (1) pre-/postsurvey design, (2) intensive longitudinal data collection throughout camp activities, and (3) qualitative analysis of pre- and postcamp one-on-one interviews. Each of these methods is described in the sections that follow.

2.2.1 Pre- and Postcamp Surveys

The quantitative surveys included measures of science and engineering interest and self-efficacy developed for this age group and shortened in previous research (Karabenick and Maehr, 2007; Lakin et al., 2019). Example items are provided in Table 3. The scale for each ranged from 1 (not at all true) to 3 (somewhat true) to 5 (very true).

Because of the casual context of data collection, most seemed not to notice that the surveys were printed the front and back, which resulted in 9 of 20 students providing usable pre- and postcamp quantitative surveys. Given the limited sample, we used the Wilcoxon signed-rank test (Gibbons, 1993) for a paired sample comparison. This nonparametric test compares the magnitude of pre-to-post changes across participants to determine if the positive changes are consistently larger than any negative changes.

At the beginning of camp, students also rated their career and life values on a survey instrument commonly used for career planning (Florida Department of Education, n.d.). Examples are included in Table 3. Nineteen of the students completed this survey (located on the front page of the instrument). The scale ranged from 1 to 4: 1 = Not

TABLE 3: Scales and example items

Scale	Items
Interest in Science (n = 5)	I like science. I would like to work in science someday.
Interest in Engineering (n = 5)	I would like to study engineering in college. I want to learn more about engineering.
Self-efficacy for Science (n = 5)	I am good at science. I believe I will receive a good grade in science class.
Self-efficacy for Engineering (n = 5)	I believe I can do well in an engineering club or camp. Even if the work in an engineering club or camp is hard, I can learn it.
Career values (n = 20, 11 individualistic, 5 altruistic, 4 creative)	*Make decisions*: Have the power to decide what I want to do and manage others. *Help society*: Do something which contributes to improving the world we live in. *Aesthetics*: Studying or appreciating the beauty of things, ideas, etc.

important, 2 = Somewhat important, 3 = Important, and 4 = Extremely important. Items included an example to explain the value. The scale included 11 items that could be classified as individualistic, five that were altruistic, and four that were relative to creativity.

2.2.2 Intensive Longitudinal Survey Design

We were interested in assessing the influence of specific activities on students' perceptions in order to localize any effects specifically to the values-framing of activities. Therefore, we developed an intensive longitudinal design with frequent, brief surveys throughout the camp. Intensive longitudinal data collection is similar to *experience sampling*, where students are asked to complete a brief survey many times in a short time frame to measure both variability in their attitudes and contextual factors that impact those attitudes (Bolger et al., 2003; Zirkel et al., 2015).

SCCT suggests that activities may impact students' career interests by influencing the three main personal beliefs: self-efficacy, personal goals, and outcomes expectations. Therefore, for each session during the camp, we wanted to briefly assess students' perception of self-efficacy for that type of engineering, interest (related to personal goals), and perceptions that the topic would help others (outcomes expectations). Although each measurement is limited in scope and reliability, by repeatedly asking our survey questions we were able to use a relatively small sample to gain the statistical power needed to explore the impacts of activities on students' short-term beliefs.

After each camp event, the students rated the activities in terms of the three rating scales shown in Fig. 1. Twenty students provided complete ratings data for seven ses-

Complete the rating after each session and complete the reflection questions.

	This kind of engineering is interesting to me. 0=Not at all 1=A little interesting 2= Pretty interesting 3= Very interesting	**I could be successful doing this kind of work.** 0=Not at all 1= Probably not 2= Probably 3= Definitely could	**This activity showed that engineers help others.** 0=Not at all 1= Help only a little 2= Probably help 3= Definitely help
Monday AM			
Monday PM			
Tuesday AM			
Tuesday PM			
Wednesday AM			
Wednesday PM			
Thursday AM			
Thursday PM			

FIG. 1: Activity rating sheet that students completed throughout the camp

sions of the camp [four afternoon and three morning sessions (140 measurement points per construct)]. To analyze patterns in their ratings, we used a hierarchical linear modeling (HLM) approach to look at variation in ratings between students and within students as they experienced different activities. In other words, we modeled the clustering of the seven time points (level 1) for each of the 20 students (level 2).

In analyzing this data, we first looked at the consistency, via the intraclass correlation, of students' ratings of interest, self-efficacy, and perceptions of helping others across various camp activities. This was to determine if there was meaningful variance to explain between and within students. Next, we analyzed which learning experiences led to higher ratings of interest, self-efficacy for engineering, or perceptions of engineering helping others. Experiences were coded by the task (0 = hands-on lab, 1 = computer app development) and topic (0 = water or solar, 1 = introduction or infrastructure). The effects were analyzed through a hierarchical model in the form of

$$OUTCOME_{ti} = \beta_{00} + \beta_{10}{*}TASK_{ti} + \beta_{20}{*}TOPIC_{ti} + e_{ti} \qquad (1)$$

where

$OUTCOME_{ti}$ included efficacy, interest, and helps-others ratings (analyzed independently)

β_{00} = mean level of interest or efficacy for that student (fixed effect)

β_{10} = slope effect of helping others rating on the mean level of interest or efficacy (fixed effect)

Level-2 equations included random effects for slope and intercept.

In the final round of HLM analysis, we looked for interactions of the different ratings. Specifically, we asked, *Do students indicate higher interest or self-efficacy in topics that they also rate as likely to help others?* This mixed model includes the cross-level effect of "helps others" on interest and efficacy ratings.

$$OUTCOME_{ti} = \beta_{00} + \beta_{10}{*}HELPSOTH_{ti} + r_{0i} + r_{1i}{*}HELPSOTH_{ti} + e_{ti}, \qquad (2)$$

where

$OUTCOME_{ti}$ includes efficacy or interest

β_{00} = mean level of interest or efficacy for that student

β_{10} = slope effect of helping others rating on the mean level of interest or efficacy

r_{0i} = level-2 (person) effect on intercept

r_{1i} = level-2 (person) effect on slope

2.2.3 Pre- and Postcamp Interviews

We interviewed 12 students at the start of camp, but only eight completed postcamp interviews due to time constraints. The interviewers asked students about career values and their perceptions of engineering with questions derived from previous research on the topic (Lakin et al., 2020; Villanueva and Nadelson, 2016). The semistructured interview for both the start and end of the camp included these questions:

- Think about your life and future career. Have you thought about what you would major in at college? What are your goals for your adult life?
- Do you know any engineers? Scientists?
- What is engineering? What does an engineer do?
- What kinds of engineering or science things do you find interesting?
- Have you considered engineering or a field of science as a future career? What do you think that career would be like?

Interviews were transcribed verbatim and reviewed for accuracy by the researchers. The transcripts were analyzed by the two lead authors using the Sort and Sift, Think and Shift approach (Maietta, 2006). This approach encouraged us to engage with the data and reflect on findings that emerged in an iterative process with attention to findings that were warranted by the data. Given the explanatory nature of this case study, we focused our analysis within each participant (threading), comparing their responses at pre- and postcamp.

The analysis process began with the lead authors individually familiarizing themselves with the data, highlighting key quotations, and constructing memos that captured the key elements and storyline for each transcript. These memos, a mechanism to document emerging thoughts and ideas about the data, served to capture the essence of interviewee responses and capture their voice. Simultaneously, the researchers engaged in ongoing written reflections to document what was already known, how this data contributes to the project aims, and to acknowledge what is new. Next, consensus around strong quotations and key elements of the data was reached.

After preliminary quotations and topics were identified, the other authors (all experts in engineering disciplines) were engaged in reading and reflecting on the selected quotations organized by student. A group consensus was reached on meaning and consistent topics and patterns. The results and discussion presented here reflect both this shared consensus as well as discipline-specific implications that these co-authors identified. A visual representation of our process is shown in Fig. 2.

2.3 Author Positionalities

Throughout the entire data collection and analysis process, we (the first two authors) constructed researcher positionality statements about our identities and subjectivities. Other team members were peripherally involved in the analyses and thus not included here. The first author grew up in a college town as a white, cisgender female. Although many readers will know that Alabama ranks as one of the lowest performing states in the country (and has for many years), Lakin's high school alma mater is one of the top schools in the state and compares well nationally. Compared to the students in this study, she was afforded advantageous educational opportunities, including many summer camps at the university and other nearby institutions, several of which focused on

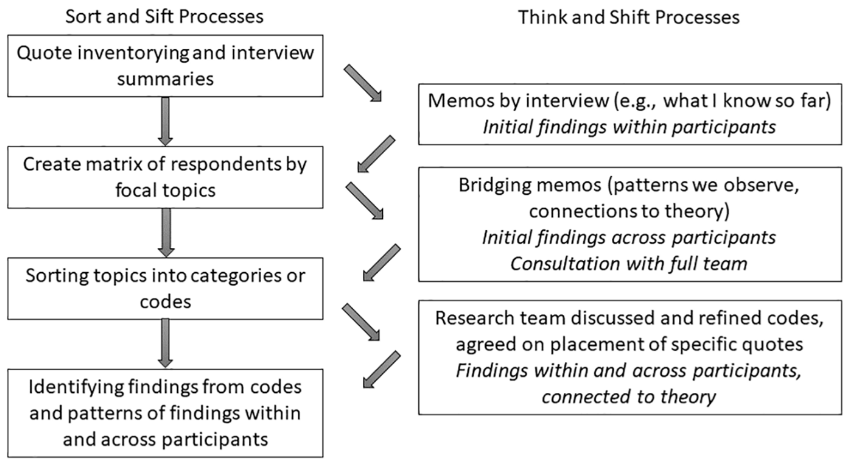

FIG. 2: Sort and Sift, Think and Shift approach adapted to our research context

science and engineering topics. She entered college at Georgia Tech as an engineering major but later decided to leave the field to major in psychology. She now studies the factors that lead others into or out of engineering and brings this personal experience to understand the pathways of others. Her experience as an Alabama native gives her a helpful, though incomplete, understanding of students growing up in the state, allowing rapport to be built on that basis. Being frank about racial issues and demonstrating (verbally and nonverbally) an openness to all responses was intended to bridge differences in age, race, and socioeconomic status. She also had several years of experience conducting evaluations in a STEM program based in their hometown, building a closer connection to their community. She also now serves on the Board of Directors for this organization to further invest in their work and success in the community.

The second author grew up in an upper-middle class household in Dallas, Texas, as a white, cisgender, female. As a woman who attended parochial institutions from K to 12 and a small, private, Jesuit, liberal art institution for undergraduate studies, she was afforded opportunities to participate in educational programs including private tutoring, college preparatory courses, and dual enrollment courses. Given her educational and social experiences, second author Mastrogiovanni recognizes her privileged status and works to be conscious of that influence. She is now an Educational Psychology doctoral student who evaluates educational programs that are intended to broaden participation in STEM for racial-ethnic minority groups. As part of this research, she spent several months working on the evaluation of a STEM education program in the students' hometown. She, therefore, brought some understanding of their community and past experiences in building rapport. Like the first author, being frank and open about racial issues was intended to build trust in discussing students' career interests and futures. She used her training and broadened perspective of education to inform her analysis of the data and interactions with participants, acknowledging the role of her privilege in understanding the data.

2.4 Protection of Vulnerable Populations

In working with youth from marginalized communities, we took care to engage both parents and students in understanding the research study and educational activities provided. Working with an existing organization in our target neighborhood, we invited parents to a "lunch and learn" information session in their community prior to agreeing to send their student to the camp. We also explained the consent process for the research aspects of the camp. Students were free to come to the camp and not participate in the research activities. Surveys were administered during "free" periods, so there was minimal pressure to participate. The researchers were frequent observers and sometimes activity facilitators, so students were used to their presence and got to know them. Students were invited to complete interviews, and a few declined to be interviewed, demonstrating their comfort with the voluntary nature of participation.

3. RESULTS

Our first research question was, *How did the camp experience overall influence students' interest in and self-efficacy for engineering as a career field?* We addressed this question with the pre- and postcamp surveys of student interest and self-efficacy for science and engineering. Changes in students' perceptions of engineering is addressed in the qualitative analysis section.

Nine students completed usable pre- and postcamp surveys on their science and engineering interest and self-efficacy. A Wilcoxon signed-rank test (one-tailed) was used to analyze the changes in students' attitudes (see Table 4). We found that only one attitude scale increased significantly, engineering self-efficacy, which rose by a small degree (0.2 scale points) but was observed to consistently increase for students at postcamp. Changes in engineering but not science are consistent with our expectations given the focus of the camp.

3.1 Intensive Longitudinal Data

Our second question, *How did individual activities throughout the camp influence students' interest, efficacy, and perceptions of engineering as an altruistic career?*, was

TABLE 4: Wilcoxon signed-rank test of pre–post differences

	Pre median	Post median	W statistic	df	CV	Result
Science interest	2.5	2.6	20.0	8	5	retain
Engineering interest	3.4	3.0	17.0	8	5	retain
Science self-efficacy	3.7	3.8	7.0	8	5	retain
Engineering self-efficacy	2.8	3.0	2.5	8	5	$p < 0.05$

addressed by the intensive surveying during the camp. Each of the dependent variables (task interest, efficacy, and helping others) was studied separately. Dummy coded predictors for task type and topic were entered separately and concurrently.

For interest, there was variation between individuals, with an ICC = 0.93, indicating that students were mostly consistent in their ratings across tasks but varied somewhat according to the task they were experiencing. Neither task type nor topic (our L-1 predictors) had a significant effect on ratings. We also considered student-level (L-2) predictors, including gender and age, but neither had a significant effect.

We conducted the same analyses for self-efficacy, and found that the ICC = 0.80, indicating somewhat less consistency at the individual level and more variation due to time point. Again, neither task type nor topic had a significant effect on ratings. However, gender had a significant effect on the intercept (b = 0.57, S.E. = 0.25, p = 0.038), where girls reported less confidence in their success than boys.

Finally, we looked at variation in the perception that the type of engineering shown would help others. Again, the ICC indicated limited variation by task (ICC = 0.93). The topic had a significant effect, with water topics being rated as more helpful to others than other topics (b = 0.43, S.E. = 0.15, p = 0.006). When the task type was added to the model, it also had a significant effect (b = –0.40, S.E. = 0.12, p = 0.001), indicating that students perceived the type of engineering as being more helpful after completing the hands-on lab activities compared to the computer app activities. See Table 5.

3.1.1 Relationship of Perceptions to Interest and Self-Efficacy

In addition to the main effects, we were interested in the interaction of help-others ratings with the interest and self-efficacy students expressed after each session. In other words, we wanted to see if students' perceptions that a type of engineering helped others would correlate to higher interest in the topic or higher self-efficacy.

We found a significant cross-level interaction where higher perceptions of helping others was associated with an increased interest in the topic (b = 0.44, S.E. = 0.12, p = 0.002). See Table 6. Perceptions of helping others also led to an increased rating for self-efficacy (b = 0.59, S.E. = 0.11, p < 0.001). Both of these findings are consistent with

TABLE 5: Effect of topic and tasks on perceptions of helping others

	Model fit				Coefficients		
	τ	**σ^2**	**ICC**	**R^2**	**Topic: Water**	**Topic: Solar**	**Task type**
Empty	0.043	0.578	0.93	—	—	—	—
Topic	0.047	0.550	0.92	0.04	0.43**	0.18	—
Task + Topic	0.052	0.509	0.91	0.10	0.36**	0.11	–0.40*

Note: *p < 0.01, **p < 0.001.

TABLE 6: Effect of help others ratings on interest and self-efficacy

		Model fit				Coefficients
	Model	**τ**	**σ^2**	**ICC**	**R^2**	**Helping others**[a]
Interest	Empty	0.055	0.730	0.93	—	—
	Help-others rating	0.085	0.516	0.86	0.23	0.41**
Self-efficacy	Empty	0.182	0.746	0.80	—	—
	Help-others rating	0.211	0.542	0.72	0.19	0.54**

Note: **$p < 0.001$.
[a]This variable was group centered.

our hypothesis that demonstrating the altruistic value of engineering can lead to at least short-term gains in interest and perception of self-efficacy.

3.2 Qualitative Findings

To address our third research question, *How did the camp experience influence students' definitions or perceptions of engineering as a career field?*, we used a qualitative approach to identifying themes and patterns in our data based on the hypothesis that students' definitions would change as a result of camp experiences, possibly aligning with discussions of values and interests.

We interviewed 12 students at the start of camp, but due to time constraints, only nine completed usable postinterviews. Table 7 provides the age and gender of each participant. All participants were African American and from the Bessemer or greater Birmingham, Alabama, region. The table also reports the quartile of that students' postcamp attitudes (1 = top quartile, 4 = bottom quartile) and their average interest in each of the three career values domains.

When asked "How do you define engineering?", all students were able to provide some kind of definition at precamp. Some students had broad and accurate definitions of engineering at the outset. Most knew at least one or specific types of engineering, such as someone who works "with robotics, cars…mechanical parts" (David), "with mathematics" (Hailey), "on computers, [and] rebuilds things" (Malik). See the first column in Table 8.

What struck us was the broad, encompassing definition that nearly every student expressed in their end-of-camp interview. Our findings indicated that student perceptions and definitions of the field of engineering changed in three areas: breadth of the field, impact of the field on everyday life, and altruistic nature of the field.

Regarding the breadth of their definitions, most students during precamp interviews provided limited definitions and perceptions of the field. Their perceptions were primarily focused on engineers working on and fixing cars and electronics, being hands-on,

TABLE 7: Interview participants and attitude survey results

Interview pseudonym	Age	Grade	Gender	Career values (mean)		Postcamp attitudes (mean)			
				Individualistic	Altruistic	Science interest	Engr. interest	Science efficacy	Engr. efficacy
Ava	14	9	Girl	NA	NA	2.8	4.8	4.6	4.0
Brianna	13	8	Girl	3.0	3.8	3.2	5.0	4.4	5.0
Chloe	13	9	Girl	NA	NA	3.4	4.2	4.4	4.2
David	15	10	Boy	3.5	3.2	2.2	5.0	4.2	3.8
Hailey	14	9	Girl	3.5	3.8	2.8	2.0	4.0	2.2
Isaiah	13	8	Boy	3.3	2.8	2.8	3.2	3.2	3.6
Jaylen	13	8	Boy	3.5	3.0	2.6	3.8	3.0	3.0
Kiara	13	9	Girl	3.1	3.4	2.6	2.2	3.4	2.6
Malik	14	10	Boy	3.1	2.6	3.4	4.2	4.2	5.0

TABLE 8: Pre- vs. postcamp definitions of engineering

Pseudonyms	Beginning of camp	End of camp
Aliyah	It's like with hands-on, like mechanical, chemical, like stuff like that. … I think about like people that help fixing cars, I think about scientists, and like nurses and doctors.	**Engineering is everything. Basically everything around us is stuff that we touch that come to contact with like, it's simple as a table, it's simple as clothing**. It's like, I didn't know it was this much engineering! I was just like fixing stuff, but woo, there's a lotta engineering 'cause you got machines and stuff and process clothes can go through. It's just a lot. … They really get involved with people 'cause civil, civil engineering that's what I really like. 'Cause public safety and stuff tie in with civil engineering, I like that.
Brianna	So, like um, build the roads and make the bridges and they do the…the…they make power, yeah. They, they work out of some of them work out of power plants and some of them like I said they build streets and figure out what to do when like [inaudible] aren't like as levels as others and things like that. So, I feel like they just are like some of the main people who make what we have today. Um, without some engineers I don't think we would have like some of the things we have today.	Engineering, **I feel like, now that I've just been through this week, earlier it was such a just broad term because like engineering can be like so many different things.** It can be like uh uh finding a way to give someone a heart… finding a way to make artificial organs or like building bridges or things like that. So, I feel like engineering is just people helping their community, people helping other people and just… They just help, I guess, that's…they help in different ways but they're helping.
Chloe	When you think of engineering you think of like people work on cars or just in factories or something like more along those lines, dealing with science and math. …work phone calls, have to deal with science, and just different things like um, you could also have uh auto mechanic, like I don't know how to say it it's not in my mind right now, 'cause I know we went to um other workshop and they came talked about it. Don't know much about it, it's a little fuzzy right now, but I mean engineer also make a lot of money.	I would say engineering is, it's a lot of different things actually, that has to do with science. **Um, because the first engineering the first thing that popped to my head was cars I just thought they built cars. But actually they do a lot like uh they build bridges, they do computer stuff—I did not know that, just it's just different parts of engineering they do.** They in the medicine, the medical field and stuff so, I did not know that until I got to camp.

TABLE 8: (*continued*)

David	Someone who works with robotics, cars… mechanical parts. …. Create things that could be cars or have motherboards, computers…anything that's electrical.	Uhhh….it could be anything….it could be anything in the world. That chair over there could've been made by an engineer. Although machines are doing everything now, **anything in the world could've been made by an engineer.**
Hailey	An engineer is someone who works with mathematics and things of that nature, right? Like a mechanical person, they are engineers.	**Engineering is dealing with our daily lives**...like bridges... well you have like different departments of engineers. You have mechanical, civil, and things like that. Engineering helps with...it deals with air pollution, plumbing, things like electricity and things like that.
Isaiah	For like a computer engineer, they would work on people's computers and fix them and work and people's phone. Possibly work on tv's, or they can sit at home and do work on the computer.	An engineer is someone who creates things. **It doesn't matter what type of engineer you are, you're still creating something or helping to make something.**
Jaylen	Someone what works on modern day things to make things better. …They could build buildings and bridges.	That it's **more than just one specific thing**...it's a large variety of things… Uhhh...science has math, technology and you can do multiple different things about almost everything in the world. … **[Engineers] help make the world better place.**
Kiara	They design. They create. They build stuff. Put together layouts. [What kinds of things?] They assemble cars, airplanes. They have rockets. There's more. I can't really think of them.	**They do a lot more than people think you do.** Ummm, like we saw a video today where they worked on some stuff underground and they are just a big part of the world and how they contribute to it.
Malik	There's different types of engineers. They can work on computers, rebuild things and maybe painting. Pretty sure painting. Painting maybe? Let's see. Building a house from the ground.	**I would say it takes like time management and creativity.** You have to like ask for help if you don't know what you're doing and keep asking until you understand, because there's lots to take in at one time to be like you're doing something.

and working in factories. After attending the camp, many students defined engineering in terms of its breadth and scope. For instance, Brianna expressed that “Engineering, I feel like, now that I’ve just been through this week, earlier it was such a just broad term because like engineering can be like so many different things.” Similarly, another student stated, “Anything in the world could’ve been made by an engineer” (David), “It’s more than just one specific thing…it’s a large variety of things” (Jaylen), and “They do a lot more than people think they do” (Kiara). It is clear that many of the participating students in the camp learned about how different engineers focus on very different domains and technological solutions.

In addition to increased recognition of the breadth of the field, many students at the end of the camp recognized that the field of engineering impacts our daily lives. Ava expressed,

> *Engineering is everything. Basically everything around us, is stuff that we touch, that [we] come into contact with like. It’s simple as a table, it simple as clothing. It’s like, I didn’t know it was this much engineering!*

Other students explained, “Engineering is dealing with our daily lives…like bridges” (Hailey), how “they are just a big part of the world and how they contribute to it” (Kiara), and how engineers “can do multiple different things about almost everything in the world” (Jaylen). Postcamp interviews highlighted that students recognized the broad and relevant impact of the field of engineering on their communities and beyond.

One striking finding in the data was that some students initially perceived the field of engineering as inherently altruistic in nature. Several students during their precamp interviews stated that engineers “come up with new ideas to help society and make more productive things” (David), “work on modern day things to make things better” (Jaylen), and “use resources that we get naturally…and using that to help other people” (Brianna). However, before the camp, students did not provide specific examples of the ways in which the field can help and serve their communities.

In contrast, by the end of the camp, many students provided concrete examples of the altruistic nature of the field of engineering. For instance, Hailey expressed that “engineering helps with…air pollution, plumbing, things like electricity…they go out and look for problems and solve them.” Other students were able to provide concrete examples of how specific concentrations in the field helped and served their communities. One student expressed that engineers “help make the world a better place… civil engineers work on roadways, bridges and buildings…computer engineers work on computers and robotics” (Jaylen) as well as how engineers can

> *give someone a heart…finding a way to make artificial organs or like building bridges or things like that. So, I feel like engineering is just people helping their community, people helping other people (Brianna).*

Similarly, Ava highlighted the communal focus of the field while providing a specific example, stating “People is the main thing. They really get involved with people 'cause…public safety and stuff tie in with civil engineering, I like that." Overall, although many students already perceived the field as a mechanism to help and serve others from the outset, students at the end of the camp were able to provide concrete examples of how the field serves their communities.

A particular point of interest was that a handful of students mentioned during their precamp interviews that engineers worked on cars. While this is partly accurate (especially given the proximity of their city to automotive manufacturing), results from prior research suggest that when students say this, they may mean working as an auto mechanic (Capobianco et al., 2011), which is incorrect. However, after the camp, one student specifically corrected this misperception:

> *… The first thing that popped to my head was cars. I just thought they built cars. But actually they do a lot like uh they build bridges, they do computer stuff—I did not know that, just it's just different parts of engineering they do. (Chloe)*

Overall, many students before attending the TCI camp had limited definitions and perceptions about the field. As these students participated in the camp, engaged in activities, and learned from professionals in the field, many of these students recognized that the field of engineering includes more than what they initially believed. These students now recognize the variety of concentrations that exist in the field, the relevant impact that their occupations have on their lives, and specific ways that each field serves and helps communities.

3.2.1 Engineering Career Interests and Altruistic Framing Influences

To address our next research question, *Were changes in students' definitions or perceptions of engineering related to altruistic or communal perceptions of engineering?*, we again used qualitative approaches to look directly at students' descriptions of their interests and future career identities to look for changes in interests or possible future selves that might have resulted from the camp experiences. See Table 9 for excerpts from each interview.

Among those students who said at the outset they were not interested in science or engineering careers, three reported in postcamp interviews that they would consider engineering as a career. For instance, Hailey stated, "…But now that I've came to this camp, I've become more interested in engineering. So, I think I might be looking into engineering now." She later went on to express how altruistic framing was the cause of this change: "Now that I hear about different parts of the world not having clean water and water being contaminated and everything, it makes me wanna go out and help people with dirty water get clean water."

Brianna was more interested in engineering postcamp and connected this change to both altruistic motivations—"they help in different ways but they're helping"—and individualistic motivations—"I need challenging… it's good to be challenged at some point." Brianna also noted that people should enter engineering "only if they really

TABLE 9: Pre- vs. postcamp engineering career interest

Trend	Interview	Precamp interests or goals	Postcamp interests or goals
New interest or career option	Aliyah	Well, I wanna help like with solving like cures and stuff and medicine. And like the science behind with the chemicals and everything.	Um, computer, I find interesting when it's like something that I really like doing in that field. And then, and then civil engineering, 'cause people is important to me. 'Cause it really ties in with public safety. … I wanna study biomedical engineering and work with medicines to find out creative, just make something up. … think it'd be fun. I mean, because I like creating stuff and I like doing stuff on my own then at the same time as a team, and then finding like cures and help for some things.
	Brianna	I like [earth science] a lot, like how things change in nature and how like one at some point of the time, like uh a mountain can be this high and then because of weathering and erosion and things like that it can be like this small, and I like things like that.	**But now that I'm just here, I'm just like engineering's something you should do, Brianna.** I'm just like ooh you like doing this, and you like doing that, and that's sometimes what an engineer does. So, if you can just find something that makes you interested, interests to go together, then um hey, that may be it for you.
	Hailey	I want to be a photographer and a designer [why photography?], I really like to explore things. And as for a designer, I like creating my own style. I dress how I feel.	I still wanna be a photographer and a baker, but now that I've came to this camp I've learned more, interested in engineering. So **I think I might be looking into engineering now**. …Cuz we did this experiment where we had to use a, ummm, so I don't know how to explain it, but he got the lens thing and put it over fire and we had to take another lens and put it into strawberries... he had blended it up and put it together to see the volume...the voltage that we could get from it. And I really enjoyed doing that. [solar panel lab]
	Isaiah	I want to be a computer engineer. … I really enjoy working with computers and technology. I really want to create a computer one day. I actually would like to have my own company fixing up computers with different parts.	I would add the **medical engineer to my background,** because I want to work in the medical field too...like a doctor or something. … chemical, and I'm still interested in civil.

TABLE 9: (*continued*)

Same career goal, but found new interests	Kiara	I wanna be a—work in the zoo field. Exotic animals maybe. I still wanna be a just plain, regular animals like dogs and stuff.	**I want to be a veterinarian, but if I do go into engineering it would probably, would have to be computer science.** [What piqued your interest?] When we made all those apps I had a really good time making all of the apps. ... [Engineering] could be a side job where I'm able to get extra money.
	David	I wanna do web design, computer science, or computer engineering. I've gotten a few certificates in some of those areas through my school and through other STEM programs I've been in. If the gaming thing doesn't work, I want to go overseas and do engineering.	**I would still want to stick to the same career.** [Any new interests?] Well, **environmental science**…. I learned that if you find different leaves with hair on it that it's basically waterproof. They said they broke down molecules and was able to make a spray and spray it on clothes and it pretty much makes it waterproof.
Saw connections of interests to engineering, engineering could be a path to same goals	Jaylen	Film production … I like how scenes changes. And it's not just about movies, but about YouTube videos as well.	Like mechanical or computer science. **Computer science because it closely aligns with putting clips and things together, that would happen in film production.**
	Chloe	When I grow up I want to be a trauma or general surgeon. … And be able to take care of my family.	Yes. … **A biomedical engineer, so yeah. …. Um, hopefully become a general surgeon. Or a trauma. I'd do that though. One of those.**
No change	Malik	I want to be a YouTuber and an architect.	What I think would be like to be an engineering major…**it wouldn't be bad but like, if that's what you want to do,** what they be doing and saying like, if that's what you want to do. … If it's your major you probably would enjoy them. I'm not saying I wouldn't enjoy it.

enjoy, like, science and math….” Isaiah and Ava also noted new areas of interest, both connecting their preexisting interest in medicine to biomedical engineering fields. Ava connected it to communal impacts— “They get involved with the people. … People is the main thing.”

Kiara and David indicated that they found new science and engineering interests, although it did not affect their career goals (large animal veterinarian and computer engineer, respectively). Neither mentioned any features of engineering that might be altruistic. However, both noted the widespread impact of engineering. David was expressive in his appreciation of how broadly engineering affects everyday life:

> *It could be anything....it could be anything in the world. That chair over there could've been made by an engineer. Although machines are doing everything now, anything in the world could've been made by an engineer.*

Kiara mentioned a specifically individualistic value—which was that engineering “could be a side job where I'm able to get extra money.”

Two other students integrated engineering into their existing interests. For example, Jaylen noted that computer science could be an avenue to film production (an interest he expressed at the outset). Chloe recognized that biomedical engineering could provide another pathway to helping others through medical treatments. Chloe had clear altruistic motives that led her to broaden her interest to engineering: “Because I really wanna help people and I really want to save lives.” She also recognized individualistic benefits in terms of variety of work— “I wanna say it wouldn't be the same everyday”—and high pay—“I mean engineers also make a lot of money.” She then noted that this career would allow her to support her family (a communal impact of high pay).

Just one student did not identify any potential links between engineering and his career interests (Malik). When asked what a typical day was like for an engineer, he focused on the importance of hard work and “they love math and science, probably both.” His definition of engineering focused on math and science and the need to have an interest in those fields to pursue engineering. He did not express altruistic or individualistic motivations.

4. DISCUSSION

Based on our theoretical framework, we predicted that experiences at camp could influence both interests and self-efficacy beliefs for future career paths in engineering (RQ1, RQ3). We also predicted that values would be an important personal characteristic for students and that their perceptions of altruistic values in activities would interact with perceptions of self-efficacy and outcomes expectations (RQ2, RQ4). Both quantitative and qualitative data addressed each question.

For RQ1, *How did the camp experience overall influence students' interest in and self-efficacy for engineering as a career field?*, there was evidence that the new views students developed were related to increased confidence about engineering as a potential pathway. In our small sample, we were limited in our statistical power to detect pre- and postcamp changes in surveyed attitudes. However, we did find a significant but modest increase in engineering self-efficacy. No change was detected in expressed engineering interest or either science attitude. This change in engineering confidence was reflected in several of the interviews as well, where some students recognized engineering as a potential path to reach their existing career goals and values. Brianna demonstrated this broadened possibility:

> ***But now that I'm just here I'm just like, 'Engineering's something you should do**, Brianna.' I'm just like 'Ooh you like doing this, and you like doing that, and that's sometimes what an engineer does.' So, if you can just find something that makes you interested, interests to go together, then, um hey, that may be it for you.*

This is consistent with SCCT (Lent et al., 2000), which predicts that student experiences that impact self-efficacy and help students perceive a field as congruent with their values will ultimately impact career pursuit.

The intensive longitudinal survey was aligned with RQ2, *How did individual activities throughout the camp influence students' interest, efficacy, and perceptions of engineering as an altruistic career?* The results of these analyses also supported the finding of an interaction of perceptions helping with interests or self-efficacy. While specific topics and tasks did not have a consistent effect on interest or self-efficacy, the perception of engineers helping others had important interactions. Consistent with our predictions and prior work on goal-congruency interventions (e.g., Brown et al., 2015a; Capobianco and Yu, 2014), perceptions that engineering in that day's activities helped others were associated with greater interest and self-efficacy with respect to that type of engineering. This suggests that framing activities in terms of altruistic impacts can lead to increased interest and self-efficacy among participants.

This lends support to the efforts by the National Academies of Engineering to enhance interest in engineering through the Grand Challenges approach (NAE, 2008). If students are more engaged when they perceive engineering as helping others or addressing important societal challenges, then framing engineering in those terms may build greater interest among students who might not otherwise consider an engineering career. An important question this raises is whether these effects are long lasting. Our data only looked at immediate impacts.

Another important purpose of the camp was to demonstrate the ways that engineers benefit society and help others in order to reshape how students thought about engineering and the opportunities it provides to meet altruistic goals. This aligns with RQ3 and RQ4, which asked how students' definitions of engineering as well as their interest in engineering changed during the camp experience.

Our analysis of their definitions of engineering and what engineers do showed that students had richer definitions that reflected this framing. By the end of the week, campers consistently remarked in their interviews on how broadly and relevantly engineers impact our everyday lives. As David put it, "[Engineering] could be anything….it could be anything in the world. …**anything in the world could've been made by an engineer.**" Several also emphasized how engineers create solutions, solve problems, and serve communities to benefit society overall. This broad view of engineering is consistent with the engineering field's own definitions (NAE, 2008, 2013), as well as prior work on public perceptions of engineering (Villanueva and Nadelson, 2016; Capobianco et al., 2011). Thus, this intervention was effective at addressing misconceptions or narrow understandings of engineering to give students an expansive and motivating definition of engineering. As Jaylen stated:

> *That it's **more than just one specific thing**...it's a large variety of things… you can do multiple different things about almost everything in the world. … **[Engineers] help make the world better place.***

His excitement in saying this really conveyed how impressed Jaylen was by the sheer breadth and impact of the engineering field. That is an experience likely to stick with a student.

RQ4 looked at how students connected changes in their career interest to altruistic or individualistic values. We found a majority of students who developed interests in engineering mentioned altruistic features of engineering, either when asked about their interests or when asked to define engineering. Others had altruistic career goals at the outset, and so the camp showed them how engineering could allow them to pursue those goals in new ways.

Other students who developed interests talked about the broad impact of engineering and the variety of work that engineering provides. These may be manifestations of individualistic values, which includes not only high pay, but a variety of work and having a respected or highly visible career. The one student who was not able to connect to any engineering interest focused only on the importance of math and science to engineering. Our previous work (authors, 2020) suggested that a narrow definition focused on math and science may not be associated with greater commitment to an engineering major.

These value affordances of engineering are all true—a career in engineering can help others, offer variety and respect, and allow a person to leverage their interest in math and science (ABET, 2019; Faulkner, 2007). Future research should explore whether a similarly high-quality camp, such as the existing K–12 outreach programs reviewed in the Introduction (Bayer Corporation, 2010; Buckley et al., 2019; Reid et al., 2016), without the altruistic framing still results in these changed perspectives of engineering as a broad field that impacts daily lives and has a positive effect on society.

The framing intervention is easily adopted by existing programs to explore this possibility. For example, Letourneau et al. (2021) demonstrated a straightforward change to their engineering challenges—adding a narrative (storytelling) element to the challenge greatly increased the quality of engineering design processes that girls engaged in. By framing existing hands-on engineering challenges with a story that demonstrates how engineering helps society, other programs may be able to achieve a broadened conception of engineering among participants.

Another important implication is that the facilitators themselves must hold accurate and broad understandings of engineering. If teachers or facilitators of events hold narrow conceptions of engineering, they are not equipped to help students broaden their perceptions (Cunningham et al., 2006; Lambert et al., 2007). Thus, framing interventions for educators may also be important to creating more accurate conceptions of engineering among K–12 students.

Consistent with prior work (authors of this work; Su and Rounds, 2015), girls in our sample all had higher altruistic career values than their individualistic values. Boys had higher individualistic values relative to their ratings of altruistic values. Despite this difference in values, we found that nearly all students expressed admiration that engineering helped others and affected our everyday lives, perspectives that are aligned well to altruistic values. Increased appreciation for the breadth and importance of engineering in our everyday lives was observed in both gender groups. Future research with larger samples of students should explore how gender and race differences in career values may interact with different framing strategies to impact students' interest in engineering.

4.1 Limitations and Future Directions with Values

We note that our sample was entirely students from one low-income community who were Black. Future research could explore how socioeconomic and racial factors may increase or change the relationship of gender to patterns in career values. While this has been explored in adult samples (Jones et al., 2020), studies focused on K–12 students and in the context of altruistic framing interventions is needed.

Several students mentioned money as a way to support their family. Future research should explore how the age or cultural background of students may influence how they perceive traditionally individualistic goals, such as a high income. Previous research (Kashefi, 2011) suggests that work experience may change the values individuals place on extrinsic rewards and that entrepreneurship can be framed in communal terms, particularly in the Black community (Jones et al., 2020). It may be that specific career value survey questions, such as the importance of making a good salary, may not directly tie to individualistic goals among this population as it has in other populations.

5. CONCLUSION

This study demonstrated that framing a summer camp around the Grand Challenges for Engineering can be effective in building a summer camp experience that leads to changes in students' appreciation of engineering as a career path. The camp experience did not always lead to changes in students' career interests, but it is encouraging that it had a positive effect on their understanding and appreciation of engineering and, in some cases, did influence students' career interests. This intervention is easy to add onto existing outreach programs, as many existing curricula and engineering challenges already do or could be modified to emphasize the prosocial or altruistic impacts of engineering (United Nations, n.d.; Blickhan et al., 2018).

Engineering clearly has a continuing issue with perceptions and misunderstandings, and the interventions related to goal congruity theory clearly demonstrate that these narrow views of engineering can deter girls and students from marginalized communities, such as students of color, from seriously exploring engineering as a career field. In our conversation around broadening participation, the Grand Challenges for Engineering effectively convey that "engineers make a world of difference" (p. 16, NAE, 2013) and may be an important ingredient in effective K–12 educational outreach to broaden interest and participation in the field.

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