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Extended Engagement in an Engineering Outreach Program at a Predominately Latinx High School (RTP, Diversity)

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Abstract

Outreach efforts often occur during a short period of time, and there have been recent recommendations for longer-term outreach programs to be implemented and studied. Extended outreach programs have the potential to further impact engineering perception and STEM confidence and enjoyment, which influence the choice to pursue engineering. To understand the impact of repeated outreach activities, we implemented a four-year engineering outreach program at a predominately Latinx high school, where 29% of the students were low-income. Starting freshman year and continuing through their four years in high school, participants engaged in two STEM activities and three engineering modules in their science classroom. Our research question is as follows:

How did extended engagement during the outreach program impact the students' (a) perception of engineering? (b) enjoyment of STEM classes/activities? (c) confidence in STEM skills? (d) interest in a STEM career?

We reached 50 students over the course of four years, with six students participating in all five activities/modules. Adapted surveys were implemented at three timepoints during the program to assess engineering perception, confidence in STEM skills, and enjoyment of STEM. We calculated descriptive statistics at the three timepoints for the six participants who completed all activities and compared descriptive statistics at the third timepoint for participants who completed all three engineering modules (n=15) and those who completed only one module (n=10). We also qualitatively analyzed open-ended response questions. Our findings suggest the extended engagement in outreach positively influenced participants' perception of engineering and enjoyment of STEM, with mixed results on STEM confidence. Perception of engineering were generally more positive for participants who completed all three engineering modules versus those who completed only one module. Further, the open-ended responses highlight the importance of repeated exposure, as participants indicated they felt safer and more comfortable with the project team over time. Our results highlight the importance of continued engagement with students in outreach and forming partnerships with classrooms, where students can get repeated exposure to engineering and build long-term relationships with STEM role models.

Introduction

Access to science, technology, engineering, and math (STEM) education for all youth remains an educational equity issue in the United States, particularly for engineering. While the Next Generation Science Standards (NGSS) added engineering to the K-12 science standards in 2013 [1], engineering is not a required subject in most school districts. Instead, engineering is provided as an elective course, if offered at all. Not only does the integration of engineering in K-12 science classrooms help student learning [2], it provides access to students who might not otherwise be exposed to engineering as a profession. Increased access to engineering in K-12 settings is an important step towards improving diversity in the field, as women and certain racial/ethnic groups remain underrepresented. Specifically, women only held 16.2% of positions in engineering occupations in 2019, while Hispanic/Latino engineers only held 8.3% of positions and Black or African American engineers only held 4.0% of positions [3]. Further, the recent growth of engineering bachelor's degrees awarded to Hispanic/Latino graduates has not matched their overall population growth in the last decade [4].

Outreach programs with designed curricula can be implemented to provide engineering content to students, particularly when teachers have limited training in engineering pedagogy [5]. Such programs are frequently organized by engineering faculty, students, and professionals to provide opportunities for K-12 students to learn about engineering professions. Outreach is important for broadening access and participation in the field, particularly for students who have limited exposure to engineering role models [6]. However, outreach programs are often a one-time event, consisting of only a single interaction with each student [7]. Even longer-term efforts to include engineering curricula in the classroom tend to reach students during one school year [e.g., 8], unless there is intentional sequencing and coordination with multiple grade levels over multiple years. After-school or out-of-school time (OST) programs can reach the same students for multiple years perhaps more easily [e.g., 9], but students do not always connect their learning in such settings back to the classroom [10]. Prior research suggests that long-term, repeated exposure to engineering influences interest in an engineering career, emphasizing the need for outreach efforts in subsequent years [11]. A recent systematic review recommends implementation of extended outreach efforts to engage young women in STEM, as short-term efforts (defined as lasting between 20 minutes and two weeks) can be less effective [12]. Prior research has also stressed the need for further mentoring and access to role models for high school students underrepresented in engineering [13], which can be accomplished through outreach. Additional research is needed on how repeated engagement in engineering outreach in classroom settings and the associated long-term mentoring influences students.

Important measures for assessing student feelings toward engineering include perception of engineering, confidence in STEM skills, and enjoyment of STEM. Outreach programs can positively influence student perception of engineering [14-17], by improving their understanding of the profession [15] and their interest in pursuing engineering as a career [17]. For example, less students struggled to identify the work of chemical engineers after attending a summer camp, and they recognized differences between scientific and engineering work [15]. Confidence in STEM skills, particularly mathematical confidence, predicts choice of a STEM major in college [18]. STEM enjoyment also predicts STEM career aspirations for high school students [19]. Therefore, the goal of our study was to develop a STEM outreach program with the freshman class at a predominately Latinx high school and work with them throughout their four years of high school. We conducted two smaller STEM activities with the students during their first two years, building toward three extensive engineering modules in the last two years. The repeated interactions were designed to build mentoring relationships between the students and the project team. We administered surveys at three timepoints to address the following research question:

How did extended engagement during the outreach program impact the students' (a) perception of engineering? (b) enjoyment of STEM classes/activities? (c) confidence in STEM skills? (d) interest in a STEM career?

Methods

Study Context and Participants

Our program served a 38-person freshman class at a local, private high school, with five activities and modules implemented during the four-year program. The project team for the outreach program (62% female, five race/ethnicities) consisted of a professor and her research group of civil and environmental engineering students (five undergraduate and 10 graduate students) from the local university. The partnership with the high school was formed through a personal connection between the professor and one of the science teachers. Twenty-nine percent of the overall student population at the high school were low-income students. The high school uses a unique cooperative education model, where all students work part-time in an internship to support the cost of their tuition. Figure 1 displays demographic information about the freshman class, including race/ethnicity, gender, and parent education. Students were primarily from groups underrepresented in engineering (e.g., 80% Latino/Hispanic and 57% female) and generally (65%) would be first-generation college students. Almost all outreach program activities were conducted in the classroom, in association with science courses across the curriculum (year 1: biology, year 2: chemistry, year 3: advanced placement (AP) environmental science, and year 4: AP physics). While we intended for the outreach activities to reach students in the freshman class (n=38) as they progressed through their science curriculum, not all students took the same sequence of science courses. Therefore, we did not reach all 38 students from the initial freshman class every subsequent year in the program. Additionally, several students outside of the initial freshman class participated in activities during year 2 through year 4 if they took an associated science course. Overall, we served 50 students during the four-year outreach program. Our analysis focuses on the following two participant subsets: the six students who participated in all five activities and modules and the 25 students who participated in Engineering Module 3.

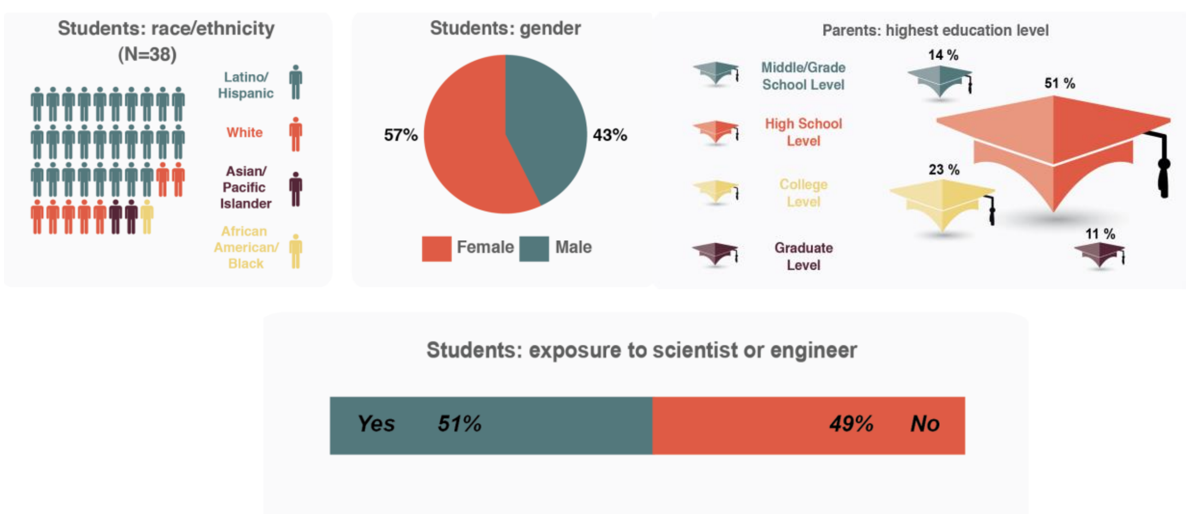

Figure 1. Key information about the overall cohort in their freshman year (n = 38)

STEM Activities and Engineering Modules

Figure 2 shows the timeline of STEM activities and engineering modules across the 4-year outreach program. The activities during the first two years were intended to introduce the students to STEM topics and to the project team (STEM Activity 1 and 2), and the modules in the last two years were intentionally deeper engagements on engineering topics (Engineering

Module 1, 2, and 3). STEM Activity 1 occurred in year 1, STEM Activity 2 in year 2, Engineering Modules 1 and 2 in year 3, and Engineering Module 3 in year 4. Aside from STEM Activity 1, each activity and module were designed by the professor on the project team in conjunction with her research group. Prior outreach materials, online resources, and input from teacher-partners were used to shape some of the activities and modules. The project team ran all activities and modules, with assistance from the science classroom teacher. Most undergraduate and graduate students on the project team participated in multiple activities and modules during the outreach program, with several students graduating before the end of the program. Below, the activities and modules are described in detail.

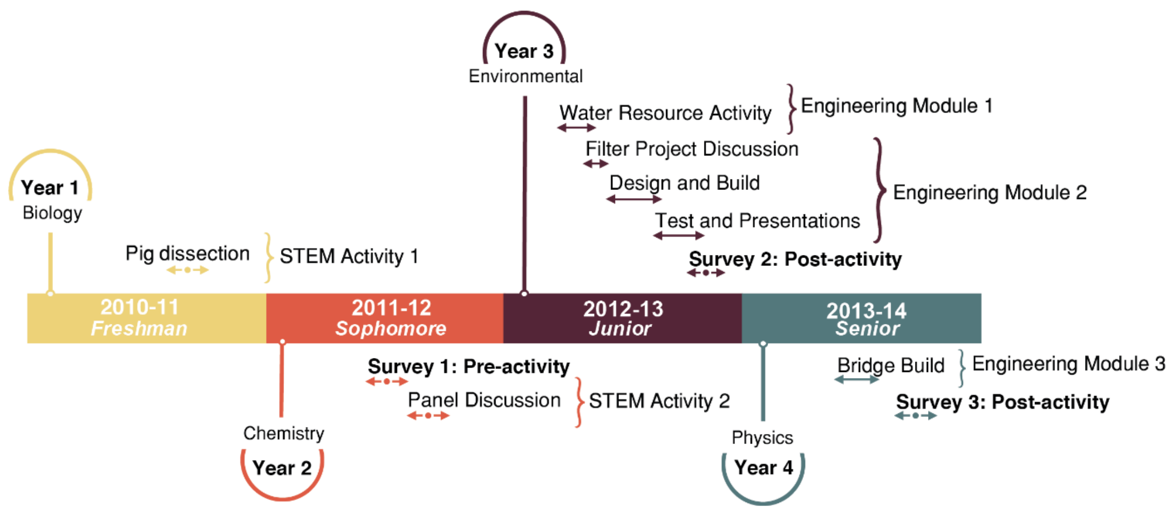

Figure 2. Timeline of STEM activities, engineering modules, and surveys over the 4-year outreach program

In the year 1 biology course, the project team led a fetal pig dissection as part of STEM Activity 1 (two meetings). We assisted the students with their dissections, provided feedback on dissection technique, and discussed the various organs. In addition, we prepared a “freshman lab-report guidelines” document and led a discussion regarding the parts of a lab report. The students followed this document to prepare their lab reports. STEM Activity 1 was intended to give the students a hands-on scientific experience, an introduction to technical writing, and an opportunity to get to know the project team members. In the year 2 chemistry course, we held a panel discussion on STEM for STEM Activity 2 (one meeting). Four members of the project team comprised the panel, and each panelist described their pathway to STEM. Their pathways to and reasons for pursuing STEM were quite diverse, as was the composition of the panel (75% female). Students had the opportunity to ask questions and interact with the panelists.

In the year 3 AP environmental science course, we conducted two engineering modules. Engineering Module 1 (three meetings) focused on water resources engineering and occurred in the fall. The project team gave two lectures on water resources engineering. Then, in a field trip to the local university, the students delineated a local watershed of their choice using the professional engineering software suite Arc GIS© (Esri; Redlands, CA) and took a tour of the environmental engineering laboratories. In Engineering Module 2 (nine meetings), which occurred in the spring, groups of three to four students were tasked with a semester-long water filter design and construction project. The project team gave three lectures on water filter design. Each group of students utilized code in Microsoft® Excel (Redmond, WA) to facilitate their filter design and validated their design with a project team member. Using a maximum of $60 per group to purchase materials, the groups constructed their filters. They tested their filters for particle removal at the local university, and each group gave a final oral presentation on their project. Materials for Engineering Module 2 include the lesson plan, problem statement, student equation sheet, an example filter schematic, grading rubric, and Excel design worksheet.

In the year 4 AP physics course, the project team conducted Engineering Module 3 (four meetings), which focused on bridge design. We gave a lecture on free-body diagrams and various types of bridge designs. Groups of two or three students completed a bridge design activity (with specifications based on Tech Day Competition [20]) in which they built bridges with toothpicks and marshmallows. The bridges were loaded until failure, and students then calculated the efficiency of the bridge, using the following equation:

$$\text{Efficiency} = \frac{External\ weight\ supported\ by\ bridge}{Self-weight\ of\ bridge} x100\%$$

Assessment Methodology

We administered surveys at three timepoints during the outreach program (Figure 2); the first before STEM Activity 2 (year 2), the second after Engineering Module 2 (year 3), and the third after Engineering Module 3 (year 4). The surveys included multiple-choice and open-ended questions that had been adapted from existing, validated pre-college question sets [21], where the wording was modified slightly to better reflect the current outreach. The survey questions addressed three topics: *perception of engineering* (Table 1; six questions and one open-ended question), *confidence in STEM skills* (Table 2; three questions), and *enjoyment of STEM classes and activities* (Table 3; four questions). We chose to include surveys on STEM in addition to engineering for two reasons: 1) Activity 1 and 2 broadly focused on STEM and 2) STEM is integral in pursuing an engineering degree, which has many math and science coursework requirements. Each *perception of engineering* question had three response options (Agree, Disagree, and Don't Know), each *confidence in STEM skills* question had four response options (Never, Sometimes, Very Often, and Always), and each *enjoyment of STEM classes and activities* question had four response options (Strongly Disagree, Somewhat Disagree, Somewhat Agree and Strongly Agree). The survey at the third timepoint also included open-ended questions about the outreach program (Table 4; five open-ended questions), only for students who participated in all three engineering modules (n=15).

Table 1. Survey questions to assess student perception of engineering

Read the following statements about what engineers might do and indicate your agreement or disagreement with each statement.
a) Mainly work on machines and computers
b) Mainly work with other people to solve problems
c) Work on things that help the world
d) Can choose to do many different kinds of jobs
e) Mainly work with things that have nothing to do me
f) I don't know what engineers do
g) What do you think engineers make? (Free response)

Table 2. Survey questions to assess student confidence in STEM skills

The table lists things you can do when you are working on school activities or assignments. Check the appropriate box to tell us how often you do each of these things.
a) I can use what I know to design and build something mechanical that works
b) I know where I can find the information that I need to solve difficult problems
c) I can explain math or science to my friends to help them understand

Table 3. Survey questions to assess student enjoyment of STEM classes and hand-on STEM activities

Here is a list of statements. Tell us what <u>*you*</u> *think about them. Select a response that indicates your level of agreement.*
a) I look forward to science class in school
b) I look forward to math class in school
c) I would rather solve a problem by doing an experiment than be told the answer
d) More time should be spent on hands-on projects in science or technology activities at school

Table 4. Open-ended questions at the conclusion of the 4-year outreach program

Please answer the following questions if you attended Engineering Modules 1, 2, and 3. Your answers will help us improve this program in the future.
a) Was the recurrent interaction with the team helpful to you?
b) Have your interactions with the team in these activities made you more likely to consider a career in science or engineering?
c) If you plan to study engineering in college, did the outreach program play any role in this decision?
d) Which of the STEM activities of engineering modules did you find the most fun?
e) From which of the STEM activities or engineering modules did you learn the most?

Data Analysis

During analysis, we scaled answers to the multiple-choice questions as follows: *engineering perception* (Agree, 1; Disagree, -1; I Don't Know, 0), *confidence in STEM skills* (Never -1; Sometimes, -0.5; Very Often, 0.5; and Always, 1), and *enjoyment of STEM classes and activities* (Strongly Disagree, -1; Somewhat Disagree, -0.5; Somewhat Agree, 0.5; and Strongly Agree, 1). For each multiple-choice question, we calculated the average of the scaled responses at each timepoint for the six students who participated in all five of the STEM activities and engineering modules. We also analyzed the scaled responses from the *engineering perception* questions at the third timepoint, where we calculated the average of the scale responses for students who participated in Engineering Modules 1, 2, and 3 (n=15) and students who only participated in Engineering Module 3 (n=10). As such, the effect of Engineering Modules 1 and 2 (12 meetings between the two modules) on perception of engineering was isolated from the effect of Engineering Module 3 (four meetings). We qualitatively analyzed the open-ended response question on *engineering perception* at the three timepoints and the open-ended response questions asked at the end of the program (Table 4), using content analysis [22]. The qualitative analysis on *engineering perception* included responses from the six students who participated in all five STEM activities and engineering modules, while the end-of-program qualitative analysis included responses from the 15 students who participated in Engineering Modules 1, 2, and 3. Our analysis specifically focuses on these two participant subsets to examine how the extended engagement in outreach impacts engineering perception, confidence in STEM, and enjoyment of STEM.

Limitations

We acknowledge several important limitations in our study. First, our analysis focuses on a small number of students in the participant subsets, with a significant portion of the data from the six students who participated in all five STEM activities and engineering modules. Not only does this limit any statistical analysis with the dataset, but it also potentially limits the generalizability of the study. To address this, we provided context by detailing the setting and the activities and modules offered as part of the outreach program. Second, the variation in course sequencing for students made it difficult to reach all students from the initial freshman class each year as intended. Third, we did not administer a survey with the students during year 1 or collect additional data to follow-up after their high school graduation. However, we collected survey responses at three different timepoints to understand how student perception, confidence, and enjoyment changes over time. Lastly, demographic information is not easily accessible for the two participant subsets included in our analysis. However, the demographic composition of the overall high school and initial freshman class (n=38) is predominately Hispanic/Latino (80%), indicating the participant subsets are likely to have a similar demographic composition. Despite these limitations, the findings from our analysis suggest the importance of repeated engagement in an outreach program, which we believe will help to inform future work.

Results

Student perception of engineering

Figure 3 shows perception of engineering over time for the six students who participated in all five of the STEM activities and engineering modules during the outreach program. For the three timepoints, the average response to each *perception of engineering* question is plotted, with bars in the plot representing average scores. Specific *perception of engineering* questions are included in Table 1 (questions a-f). The question format varied such that positive scores for questions b, c, and d (left panel) indicate a positive sentiment towards engineering, while positive scores for questions a, e, and f (right panel) indicate a negative sentiment towards engineering. Their sentiments toward engineering became more positive for five of the six survey questions during the four-year program. The students moved away from the stereotypical perception that engineers mainly work on machines and computers (Figure 3, question a). This change in perception was further evidenced by the shift in their open-ended response to question g (Table 1) in which students initially perceived engineers as typically building “better computers” to a wider variety of answers incorporating biotechnology, civil, and mechanical engineering fields. Students increasingly recognized that engineers work collaboratively to solve problems facing people (Figure 3, questions b and c). They also increasingly felt that engineers could choose among many kinds of jobs (Figure 3, question d) and that they understood what engineers do (Figure 3, question f). Although, on average, the students felt that engineers work on things that are relevant to their lives, no consistent impact of the outreach program on that point was observed over time (Figure 3, question e).

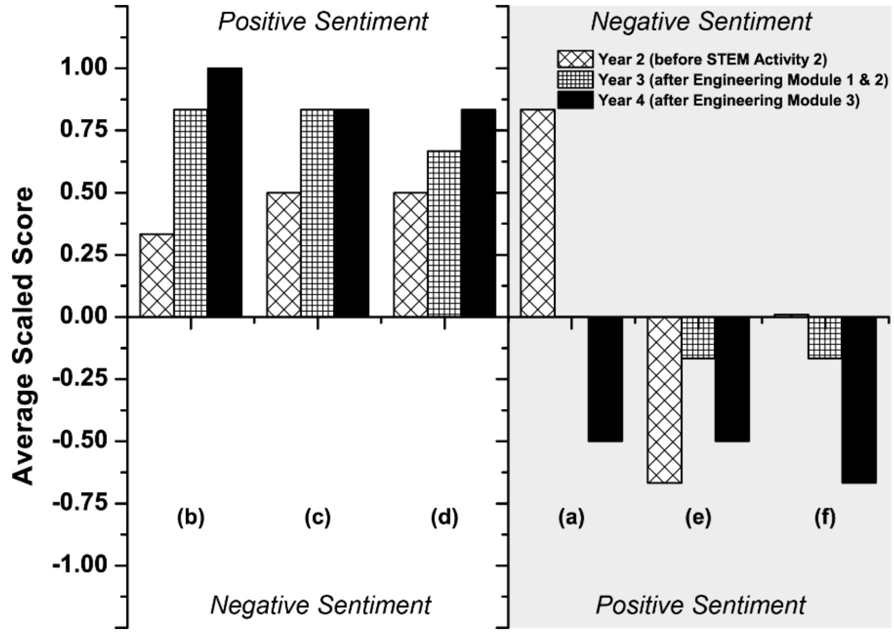

Figure 3. Perception of engineering over time during the outreach program. Questions: a) Mainly work on machines and computers; b) Mainly work with other people to solve problems; c) Work on things that help the world; d) Can choose to do many different kinds of jobs; e) Mainly work on things that have nothing to do with me; f) I don't know what engineers do

The impact of Engineering Modules 1 and 2 on perception of engineering

Figure 4 displays the average responses for *perception of engineering* of students who participated in Engineering Modules 1, 2, and 3 (n=15) and students who only participated in Engineering Module 3 (n=10). The average responses from the third timepoint are plotted, with the bars in the plot representing average scores. Similar to Figure 3, the *perception of engineering* questions were included in Table 1 (questions a-f), and positive scores either indicate a positive (questions b, c, and d) or negative (questions a, e, and f) sentiment toward engineering. Through this comparison, the impact of the extensive Engineering Modules 1 and 2 could be assessed on student perception of engineering. For five of the six survey questions, the students who participated in all three Engineering Modules had more positive perceptions of engineering than did their counterparts who only participated in Engineering Module 3. These data suggest that participation in Engineering Modules 1 and 2 made students more aware of how engineers do their work and what kind of work they do (Figure 4, questions a and e) and that engineers could choose their career from among many kinds of jobs (Figure 4, question d).

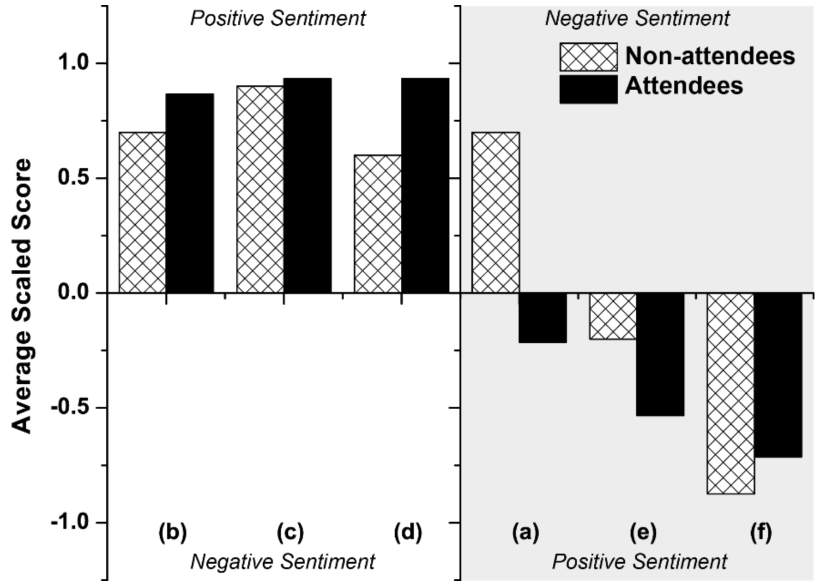

Figure 4. Impact of extensive Engineering Modules 1 and 2 on perception of engineering. Attendees participated in Engineering Modules 1, 2, and 3 (n=15), and non-attendees only participated in Engineering Module 3 (n=10). Questions: a) Mainly work on machines and computers; b) Mainly work with other people to solve problems; c) Work on things that help the world; d) Can choose to do many different kinds of jobs; e) Mainly work on things that have nothing to do with me; f) I don't know what engineers do

Student confidence in STEM

Figure 5 shows confidence in STEM skills over time for the six students who participated in all five of the STEM activities and engineering modules during the outreach program. For the three timepoints, the average response to each *confidence in STEM skills* question is plotted, with bars in the plot representing average scores. Specific *confidence in STEM skills* questions were included earlier in Table 2 (questions a-c). Positive scores indicate confidence, while negative scores indicate doubt. Student confidence in their STEM skills generally improved over the course of the outreach program, with some mixed results. While student doubt in their ability to design and build something mechanical (Figure 5, question a) lessened over time, they still felt some doubt at the end of the outreach program. From year 2 to year 4, the students showed an increase in confidence with respect to their ability to find information to solve problems (Figure 5, question b), although this confidence lessened after Engineering Module 3. Confidence in explaining math/science to their friends (Figure 5, question c) was the most resistant, showing no change after the first two engineering modules and only a slight increase after the third engineering module. Overall, students reported increases in confidence for inquiry-based learning, including building and information gathering, but these did not translate into substantial gains in confidence for explaining math/science to others (Figure 5, question c).

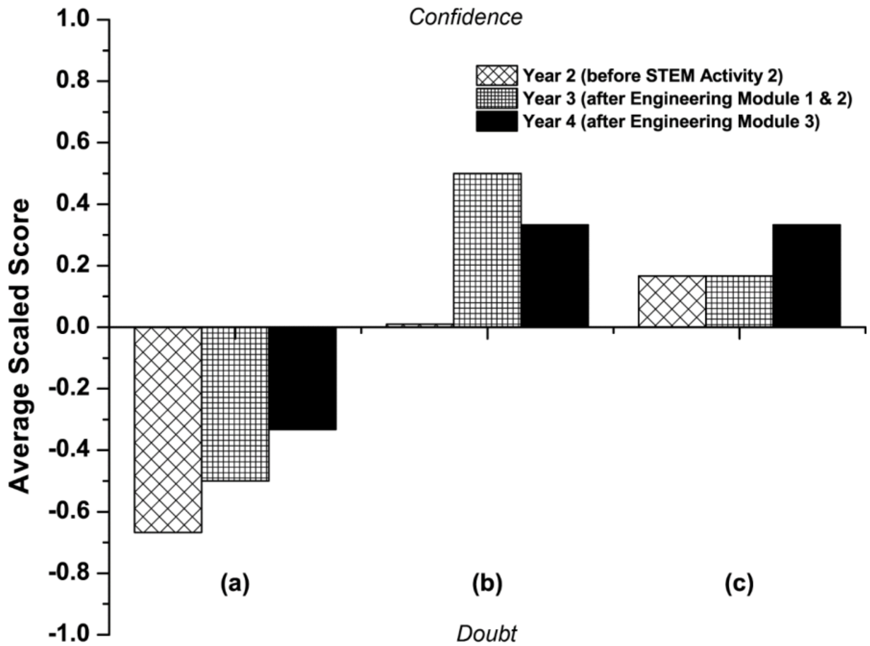

Figure 5. Confidence in STEM skills over time during the outreach program. Questions: a) I can use what I know to design and build something mechanical that works; b) I know where I can find the information that I need to solve difficult problems; c) I can explain math or science to my friends to help them understand

Student enjoyment of STEM and hands-on STEM activities

Figure 6 displays enjoyment of STEM classes in school and hands-on STEM activities over time for the six students who participated in all five of the STEM activities and engineering modules during the outreach program. For the three timepoints, the average response to each *enjoyment of STEM classes and activities* question is plotted, with bars in the plot representing the average scores. Specific *enjoyment of STEM classes and activities* questions were included earlier in Table 3 (questions a-d). Positive scores indicate a positive sentiment, while negative scores indicate a negative sentiment. The students liked their science and math classes most during year 3 (Figure 6, questions a-b); this coincided with the project team's most substantial involvement with the students (Engineering Modules 1 and 2, for 33 hours), though a causal relationship cannot be verified. Students showed an increase in enjoyment of experimental activities and desire for more hands-on STEM activities over time (Figure 6, questions c-d), particularly during year 4. From the end-of-program open-ended response questions (Table 4; n=15), many students indicated interest in more hands-on learning experiences similar to those provided during the program. Further, students felt that hands-on experiences made the material more accessible. For example, one student stated that "*the trial and error*" in the projects "*helped them learn more*", which suggests the applied scenarios facilitated learning and pulled students out of routine problem and solutions work.

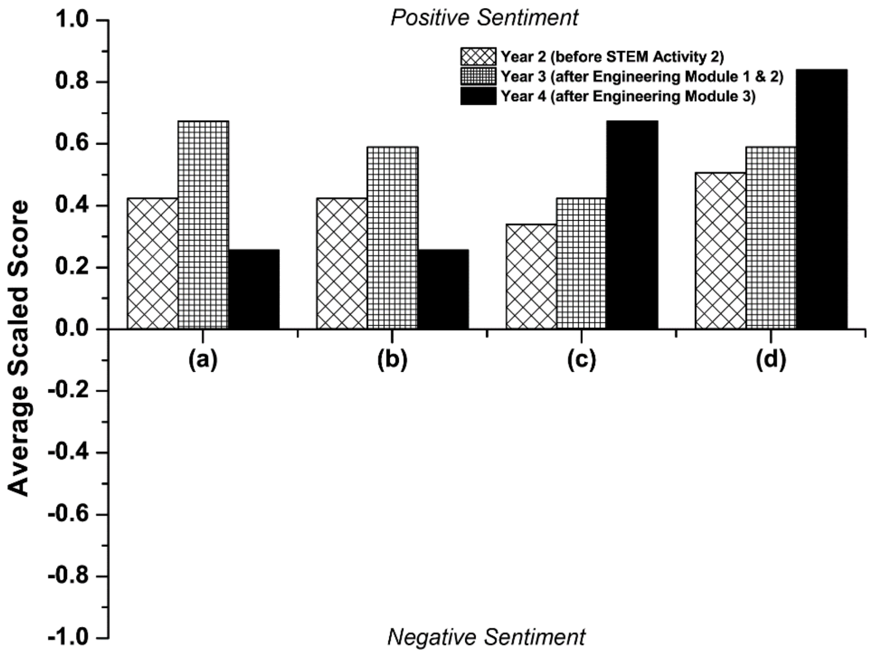

Figure 6. Enjoyment of STEM classes and hands-on activities over time during the outreach program. Questions: a) I look forward to science class in school; b) I look forward to math class in school; c) I would rather solve a problem by doing an experiment than be told the answer; d) More time should be spent on hands-on projects in science or technology activities at school

Additional findings from end-of-program open-ended response questions

Students who participated in Engineering Modules 1, 2, and 3 (n=15) responded to the end-of-program open-ended questions, which were included previously in Table 4. Overall, their responses suggest interactions with the project team positively contributed to their experiences in the outreach program. Notably, students expressed feeling comfortable in the environment created by the project team during the program. They indicated their comfort through statements such as, *"Because I could recognize the [team], I felt safer asking questions"* and *"I became more comfortable with the team and was more willing to ask questions".* Students engaged more freely during the learning process because of the repeated interactions with the project team, as illustrated from their responses. The composition of the project team also influenced level of student comfort and encouraged their engineering aspirations by showing people like themselves as engineers. Approximately 50% of the open-ended responses commented on the diversity of the project team. For example, students remarked on the gender representation within the team, with comments such as "*I felt proud seeing women in engineering*" and "*Seeing women being engineers made me feel like I can do it*". Students also noted the representation of racial and ethnic groups, with comments such as, "*It helped me see that minorities can do these things*" and *"… I wasn't intimidated – I like that it was a diverse group of people*."

Discussion

We show the impact of a four-year engineering outreach program at a predominately Latinx high school, during which students engaged in two STEM activities and three engineering modules in their science classrooms. Overall, students' perception of engineering became increasingly positive as they engaged in the engineering modules. Participation in multiple engineering modules also improved awareness of the work of engineers and their career options. Students expressed the highest enjoyment of their STEM classes during the most intensive engineering modules (year 3) and had an increased interest in self-directed, hands-on learning and problem-solving during the program. The structure of the program, with the repeated interactions between the students and project team over time and the diversity of the project team contributed to an environment where students felt comfortable. However, the students' confidence in their STEM skills during the outreach program varied; in particular, their self-confidence in explaining math/science to others was resistant to change. The continued engagement with diverse mentors in engineering might be particularly important for high school students from underrepresented racial/ethnic groups, as suggested previously [13].

Our study illustrates both the benefits of an extended outreach program and the difficulty involved with reaching the same group of students over multiple years in a classroom setting. In our analysis of the two participant subsets, repeated exposure to the STEM activities and engineering modules positively influenced engineering perception, particularly in understanding what engineers do. The outreach program provided more than 56 hours of engagement over four years for the six students who participated in all activities and modules. Similarly, the project team met with the 15 students who participated in all three engineering modules 16 times during the two-year period. Our study responds to a recent call for educators and researchers to engage students in longer-term outreach [12] and adds to the literature that emphasizes that repeated interactions during engineering outreach matter [11]. Our finding that students who participated in three engineering modules had more positive perceptions of engineering compared to those who participated in one module particularly illustrates the importance of repeated outreach efforts. The inclusion of different engineering modules during the last two years likely influenced engineering perception, as students learned about the work of engineers in different fields. Therefore, in-depth exposure to different types of engineering work might be necessary to positively influence engineering perception and teach high school students what different engineers do. We worked with a smaller, private high school (initial freshman class of 38 students); partnership in long-term outreach with a larger high school is needed to reach larger numbers of students over multiple years, which will allow statistical analysis. Additional work is needed, as our findings may not be generalizable to all settings and to understand if repeated outreach efforts during one year (as opposed to multiple years) would have similar effects.

Fifty-six percent of the 15 students who attended all three engineering modules stated that the outreach program helped them choose a career path in STEM, which suggests the program components added to their regular science curriculum. The presence of diverse mentors on the project team and their recurring interactions with students likely contributed to this outcome, as evidenced in the open-ended response questions. Within the overall project team, 62% of team members were female, and five race/ethnicities were represented. This is more diverse than both the engineering workforce [3] and engineering bachelor degree earners [4], particularly in regard to gender representation. As students commented on how the representation of both women and underrepresented racial groups helped them visualize themselves as engineers, our study points to the importance of diverse mentors engaging in long-term outreach. Several mentors on the project team identified as Hispanic/Latino, and the students were predominately Hispanic/Latino (80% of the initial freshman class). Our findings point to the importance of showing diversity in engineering within outreach programs, as well as students seeing mentors who look like themselves (with respect to both race/ethnicity and gender).

While STEM enjoyment was positively influenced during the program, there were mixed results around STEM confidence. While both enjoyment and confidence predict STEM career choice [18, 19], confidence might be more difficult to impact during outreach programs as compared to enjoyment. Our finding that student confidence in explaining math/science to their friends was resistant to change is notable, as mathematical confidence has been found to predict choice of a STEM major [18]. The structure of the outreach program likely influenced this finding; many of the activities and modules were hands-on, self-directed learning opportunities. Students expressed enjoyment of such methods of learning following their exposure during the outreach program. However, we did not specifically structure the program or add supports to build student confidence in STEM. In an outreach setting, students might need intentionally designed supports to gain confidence in STEM. For example, students could practice explaining science and math concepts to their friends or in front of the class and receive positive feedback from the project team, as part of the activities and modules. Positioning students as experts and using specific discourse to emphasize their math and science skills and competencies could have a greater influence on STEM confidence, as prior studies highlight the importance of recognition in science identity development [e.g., 23].

Conclusions & Future Work

We found that extended engagement in a four-year outreach program improved students' perception of engineering, enjoyment of hands-on STEM activities, and level of comfort with the project team, who served as a diverse team of mentors. However, there were mixed results around confidence in STEM skills, which suggests that further supports are needed to intentionally structure the program in a way that builds student confidence. Our study emphasizes how long-term outreach efforts can be formed in partnerships with science classrooms to integrate engineering into the curriculum. Such programs could be particularly important for students from underrepresented racial/ethnic groups in engineering. Although there are limitations in the study due to our sample size and lack of statistical analysis, our findings suggest the importance of extended outreach and the need for additional research on this topic. Future work should include a larger sample size, so that statistical analysis can be conducted.

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References

[1] National Research Council, *Next generation science standards: For states, by states*. Washington DC: The National Academies Press, 2013.

[2] S. Purzer and J. P. Quintana-Cifuentes, "Integrating engineering in K-12 science education: Spelling out the pedagogical, epistemological, and methodological arguments," *Disciplinary and Interdisciplinary Science Education Research,* vol. 1, no. 1, pp. 1-12, 2019.

[3] National Science Foundation, "Women, minorities, and persons with disabilities in science and engineering," National Science Foundation, National Center for Science and Engineering StatisticsSpecial Report NSF 19-304, 2019, Available: http://www.nsf.gov/statistics/wmpd/.

[4] American Society for Engineering Education, "Engineering and Engineering Technology by the Numbers 2019," Washington, D.C.2020.

[5] S. Brophy, S. Klein, M. Portsmore, and C. Rogers, "Advancing engineering education in P-12 classrooms," *Journal of Engineering Education,* vol. 97, no. 3, pp. 369-387, 2008.

[6] M. F. Bugallo and A. M. Kelly, "Engineering outreach: Yesterday, today, and tomorrow," *IEEE Signal Processing Magazine*, vol. 34, no. 3, pp. 69-100, 2017.

[7] J. Vennix, P. Den Brok, and R. Taconis, "Perceptions of STEM-based outreach learning activities in secondary education," *Learning Environments Research,* vol. 20, no. 1, pp. 21-46, 2017.

[8] K. Bethke Wendell and C. Rogers, "Engineering design-based science, science content performance, and science attitudes in elementary school," *Journal of Engineering Education*, vol. 102, no. 4, pp. 513-540, 2013.

[9] J. D. Adams, P. Gupta, and A. Cotumaccio, "Long-Term Participants: A Museum Program Enhances Girls' STEM Interest, Motivation, and Persistence," *Afterschool Matters*, vol. 20, pp. 13-20, 2014.

[10] A. J. Gonsalves, ""Science isn't just what we learn in school": Interaction rituals that value youth voice in out-of-school-time science," *Canadian Journal of Education,* vol. 37, no. 1, pp. 185-208, 2014.

[11] J. Blandino and J.-M. Hardin, "Assessing the Impact of Engineering Outreach Frequency on Middle-school Students' Interest in Engineering," presented at the ASEE Annual Conference & Exposition, Seattle, WA, 2015.

[12] E. Prieto-Rodriguez, K. Sincock, and K. Blackmore, "STEM initiatives matter: results from a systematic review of secondary school interventions for girls," *International Journal of Science Education,* vol. 42, no. 7, pp. 1144-1161, 2020.

[13] J. P. Martin, D. R. Simmons, and S. L. Yu, "The role of social capital in the experiences of Hispanic women engineering majors," *Journal of Engineering Education,* vol. 102, no. 2, pp. 227-243, 2013.

[14] P. Molina-Gaudo, S. Baldassarri, M. Villarroya-Gaudo, and E. Cerezo, "Perception and intention in relation to engineering: A gendered study based on a one-day outreach activity," *IEEE Transactions on Education*, vol. 53, no. 1, pp. 61-70, 2009.

[15] R. Hammack, T. A. Ivey, J. Utley, and K. A. High, "Effect of an engineering camp on students' perceptions of engineering and technology," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 5, no. 2, pp. 10-21, 2015.

[16] E. Oware, B. Capobianco, and H. A. Diefes-Dux, "Young children's perceptions of engineers before and after a summer engineering outreach course," in *Frontiers In Education Conference*, Milwaukee, WI, 2007.

[17] C. R. Scherrer, "Outreach emphasis on the human impact potential of engineering improves perceptions of underrepresented groups," *Journal of Women and Minorities in Science and Engineering*, vol. 19, no. 1, pp. 37-45, 2013.

[18] M. W. Moakler Jr and M. M. Kim, "College major choice in STEM: Revisiting confidence and demographic factors," *The Career Development Quarterly*, vol. 62, no. 2, pp. 128-142, 2014.

[19] W. Ahmed and R. R. Mudrey, "The role of motivational factors in predicting STEM career aspirations," *International Journal of School & Educational Psychology*, vol. 7, no. 3, pp. 201-214, 2019.

[20] University of Detroit Mercy. (2016). *Tech Day Competition*. Available: https://eng-sci.udmercy.edu/research/files/2016-Toothpick-bridge.pdf

[21] Assessing Men & Women in Engineering. (2011). *AWE Assessing Men and Women in Engineering Instruments*. Available: http://aweonline.org/about.html

[22] K. Krippendorff, *Content analysis: An introduction to its methodology*, 4th ed. Thousand Oaks, CA: Sage Publications, 2019.

[23] R. Hughes, J. Schellinger, and K. Roberts, "The role of recognition in disciplinary identity for girls," *Journal of Research in Science Teaching*, vol. 58, no. 3, pp. 420-455, 2021.