The Role of Hands-On Engineering Technology Summer Camps in Attracting Underrepresented High School Students to STEM Majors

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Abstract

The future career choices of high school students are greatly influenced by their knowledge and understanding of different professions. However, research has shown that students, particularly underrepresented minority groups, may have preconceived notions about science, technology, engineering, and math (STEM) that can discourage them from choosing it as a career. The representation of women in STEM fields also varies greatly, with women being underrepresented in fields such as engineering, computer science, and other physical sciences despite making up a majority of employees in health-related fields. To address these issues, the Division of Engineering Technology at Florida Agricultural and Mechanical University (FAMU) organized a hands-on engineering technology summer camp to attract underrepresented high school students, including minorities and women, to STEM fields, particularly engineering and engineering technology.

The one-week summer camp included hands-on activities and trivia games designed to improve students' cognitive understanding of STEM topics and boost their self-confidence. The camp included 15 high school minority students (9 males and 6 females) from north and central Florida, and the results indicated a positive impact on their understanding of different STEM topics. The curriculum was tailored around construction, civil, electrical, and electronic engineering subjects and was designed to improve the students' teamwork and oral presentation skills. The surveys conducted during the camp showed that the students found the hands-on activities and trivia games to be the most beneficial and improved their understanding of STEM topics. These results provide the university with an effective and sustainable approach to recruiting underrepresented minority students to STEM majors. The results of the camp suggest that hands-on engineering technology summer camps can attract underrepresented high school students to STEM majors and allow them to engage in authentic engineering design experiences and learn about the various careers available in the field. The key components of successful hands-on engineering technology summer camps include hands-on activities, trivia games, and a focus on boosting self-confidence and teamwork skills.

Keywords: Hands-on, STEM, summer camp, underrepresented minorities, engineering technology

Introduction

The fields of science, technology, engineering, and mathematics (STEM) are essential for addressing society's complex problems and driving innovation [1, 2]. However, minority students, including those who identify as Black, Hispanic, Native American, and Pacific Islander, are underrepresented in STEM fields [3-5]. One strategy for increasing the representation of minority students in STEM is to provide them with early exposure to the engineering field through hands-on engineering technology summer camps. These camps allow students to engage in authentic engineering design experiences and learn about the various careers available in the engineering field [6, 7].

Hands-on summer camps for high school students in the fields of STEM have become increasingly popular in recent years [8-10]. These camps allow students to learn about and explore various STEM disciplines through hands-on activities, experiments, and projects [8]. The benefits of such camps are numerous, including the development of critical thinking and problem-solving skills [11], the opportunity to work with like-minded peers and mentors [8], and the chance to learn about careers in STEM fields [10]. In this article, the authors review the literature on high school STEM hands-on summer camps and discuss their potential impact on student learning and career development. Also, the paper outlines the hands-on activities of the summer camp hosted on campus in the summer of 2022 and their impact on participant students.

Background

According to the U.S. Bureau of Labor Statistics, as of 2021, there were approximately 10 million workers in STEM fields. This number is expected to increase by 11% by 2031—a growth rate that is more than twice as fast as all other occupations. Additionally, the median annual salary for STEM occupations is significantly higher than that of non-STEM occupations, with $95,420 in 2021 compared to $40,120 [12]. Universities should and are providing STEM programs to prepare students for the job market, encourage scientific discovery and national security, train future teachers in their fields, and keep current engineers up-to-date on the latest advancements [13]. However, universities face challenges in recruiting students in STEM majors due to the increasing demand for such programs in the job market [14].

Students' knowledge about a profession can significantly influence their career decisions. However, research has found that students often hold stereotypical views of engineers, which can hinder engineering as a career choice [15]. One way to address this issue is through outreach programs exposing students to engineering and providing them with hands-on field experiences [13, 16]. This study aims to evaluate the effectiveness of a summer engineering outreach camp in increasing high school student's interest in engineering and changing their perceptions of the field. Minority students are underrepresented in the areas of STEM. According to the National Science Foundation, underrepresented minorities made up only 9% of the STEM workforce in 2017 [17]. This underrepresentation is concerning because a diverse STEM workforce is essential for addressing society's complex problems and driving innovation [18]. Therefore, it is crucial to understand the factors that contribute to the underrepresentation of minority students in STEM and to develop strategies for increasing their representation in these fields.

Factors Contributing to the Underrepresentation of Minority Students in STEM:

A lack of access to quality STEM education significantly contributes to the underrepresentation of minority students in STEM. Minority students are more likely to attend schools with limited resources and less experienced teachers [2, 19]. These schools may not have the resources or support to provide high-quality STEM education, which can hinder the ability of minority students to succeed in STEM subjects. In addition, minority students may have less access to extracurricular STEM programs and opportunities, such as science fairs and robotics clubs, which can provide valuable experience and support for pursuing a career in a STEM field [20].

Negative stereotypes and biases also contribute to the underrepresentation of minority students in STEM. Research has shown that minority students may be less likely to pursue STEM careers due to negative stereotypes about their ability to succeed in these fields [19]. In addition, minority students may face discrimination and bias within STEM education and workplaces, which can discourage them from pursuing these careers [20].

A lack of support and mentorship for minority students is another factor contributing to the underrepresentation of minority students in STEM. Minority students may feel isolated within STEM classrooms and workplaces and may not have access to the same level of support and guidance as their non-minority peers [20]. This lack of support can make it more difficult for minority students to succeed in STEM fields and pursue STEM careers.

Strategies for Increasing Representation of Minority Students in STEM:

One way to address the issue of a shortage of engineers is to focus on implementing effective tactics during the K-12 education system. Looking back at the literature, the authors have identified several strategies that are effective in increasing the representation of minority students in STEM fields:

- Increasing funding for STEM education in under-resourced schools: Providing additional resources and support for STEM education in schools that serve underrepresented communities can help to increase the number of minority students who have access to quality STEM education [21, 22].
- Promoting diversity and inclusion within STEM classrooms and workplaces: Creating a welcoming and inclusive environment for all students and employees and actively recruiting and retaining a diverse workforce and student body can help to increase the representation of minority students in STEM fields [22].
- Providing support and mentorship for minority students: Offering support and mentorship for minority students can help to increase their persistence and success in STEM fields. This can include providing access to academic and career resources and offering mentorship and leadership development opportunities [21, 22].
- Hands-on engineering technology summer camps: Providing underrepresented high school students with the opportunity to participate in hands-on engineering technology summer camps can be an effective strategy for increasing their interest in and participation in STEM fields [13, 21, 22].
- Engaging with underrepresented communities: Outreach and engagement with underrepresented communities can help to increase awareness and interest in STEM fields among minority students. This can include providing opportunities for students to learn about and explore STEM subjects, as well as hosting events and workshops to promote STEM education [2, 13].

Previous studies have found that hands-on, design-oriented activities can increase students' engagement and interest in engineering [13, 23]. Several studies have examined the effectiveness of hands-on engineering technology summer camps in increasing the representation of underrepresented students in STEM majors. A recent study found that participation in a hands-on engineering technology summer camp was associated with increased interest in pursuing an engineering degree among underrepresented high school students [24]. Another study by Dean Hughes [25] found that underrepresented high school students who participated in a hands-on engineering technology summer camp had higher levels of self-efficacy in engineering and were more likely to enroll in an engineering major in college compared to a control group.

This study describes the efforts of the faculty in the Division of Engineering Technology in the School of Architecture and Engineering Technology at Florida Agricultural and Mechanical University (FAMU) to host a summer camp on campus in the summer of 2022 and its impact on participating students.

Key Components of Successful Hands-On Engineering Technology Summer Camps:

In order to ensure that FAMU's summer camp was successful, the team identified key principles to guide the recruitment, selection, curriculum, and class design. Research has shown that certain key elements are essential for hands-on engineering technology summer camps to be successful in attracting underrepresented students to STEM majors. These elements include:

- Engaging and challenging curriculum: The camp should offer a variety of STEM activities that are age-appropriate, hands-on, and aligned with the student's interests and abilities [25].
- Qualified and passionate instructors: The camp should have experts in their field, able to effectively convey complex concepts, and passionate about inspiring and educating students in STEM [26].
- Proper facilities and equipment: The camp should have the necessary facilities to support the hands-on activities, such as a well-equipped science lab or a robotics workshop [6, 27, 28].
- Small class sizes: The camp should have small class sizes to ensure that each student gets the individual attention they need to succeed [29, 30].
- A balance of structured and unstructured activities: The camp should offer a balance of structured, teacher-led activities and unstructured, student-led activities to allow for creativity and exploration [31, 32].
- Regular progress and feedback: The camp should provide regular progress and feedback to students, so they can see how much they have learned and what areas they need to focus on [33, 34].
- A final project or presentation: The camp should culminate in a final project or presentation for students to showcase what they have learned and to build their confidence in presenting their work [13, 35].

Summer Camp Recruitment and Selection

The team employed a multi-faceted approach to recruiting students for the summer camp at FAMU. This included distributing flyers and holding class presentations at high schools in Leon County, FL, with a majority of students from underrepresented groups. This approach allowed for the reach out to a diverse group of students and encouraged them to participate in the camp. The distributed flyers included an online application survey link, which helped determine the optimal class size and curriculum. The survey also provided the team with a selection pool of students. Additionally, it helped identify students who were particularly interested in the camp, enabling a more tailored and effective learning experience by focusing on their specific interests and needs.

The team received 31 applications for the summer camp, 18 from males and 13 from females. Figure 1 provides specific information on the grade levels of the applicants before the application deadline. The team analyzed the data provided by the survey and application to plan the optimal class size and curriculum to be taught that would cater to the majority of the campers. This helped create a more tailored and effective learning experience for the campers.

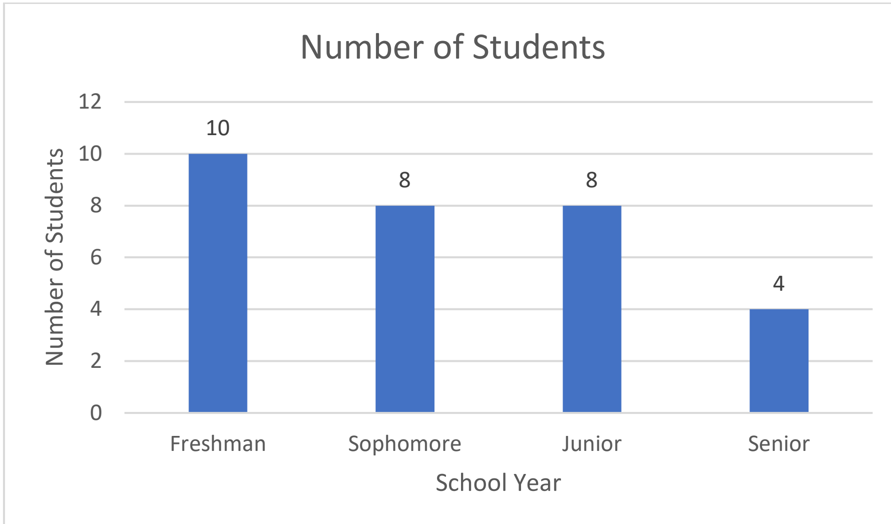

Figure 1. School Grade Distributions of Applicants

According to research, there is a general consensus that class size plays a crucial role in student learning outcomes, and smaller class sizes are associated with better student achievement. A study by the National Center for Education Statistics (NCES) in the U.S. found that students in smaller classes (of 13-17 students) tend to have higher academic achievement than students in larger classes (of 22 or more students) [36, 37]. Given this and the limited resources available, the team decided to select and invite 15 students (9 males and 6 females) to the camp based on their GPAs. The average GPA of the selected campers was 3.42.

The university does not have designated funds to cover summer camps. However, the cost of running the summer camp at a minimum includes instructors' stipends or salaries for the duration of the camp and materials needed to run the camp. In addition to these expenses, the Engineering Technology summer camp provided lunch for the campers and instructors, notebooks, and t-shirts. The funding for these items was from a few alums and construction-related organization donors, with students only being required to pay a $50 commitment fee. Summer programs need sustainable funding sources to continue supporting camps to reach underrepresented communities that can not afford to pay for a summer camp.

Camp Curriculum

The camp curriculum was designed to meet the goals of the FAMU engineering technology camp: to introduce high school students to STEM concepts and to inspire them to pursue an engineering degree and career. To achieve this, students were exposed to a wide range of hands-on engineering projects and technical activities that showcased the various aspects of engineering. The activities were divided into three types of activities:

1. Lecture sessions (early morning): introduce and explain the topics, providing students with the necessary background knowledge to understand the concepts more deeply.
2. Hands-on and lab activities (late morning and afternoon): allow students to practice and apply the concepts they had learned in the lecture.
3. Trivia games (afternoon): test the students' understanding of the topics, allowing the instructors to gauge their comprehension levels and see if they have fully grasped the concepts.

The camp core curriculum was selected to spark interest in engineering-related fields and reduce the anxiety associated with entering these fields. The activities were crafted to be enjoyable and relate to real-world engineering problems while offering the best chance for team-based problem-solving in a limited amount of time. The daily camp schedule (shown in Figure 2) was rigorously adhered to ensure smooth transitions and student satisfaction. Pre- and post-camp surveys were administered to assess students' attitudes toward engineering and their perceptions of the field. The survey included both multiple-choice and open-ended questions. The camp started by giving the campers an introduction to the camp and then followed a tour around the school of Architecture and Engineering Technology (SAET).

July 11- 15, 2022

Day	Time	Mon	Tue	Wed	Thu	Fri
Drop off	**8:00 - 8:30**	**Drop off**	**Drop off**	**Drop off**	**Drop off**	**Drop off**
Lectures	**8:30 - 9:00**	Pre-survey	Introduction to circuits (Leon)	Introduction to Surveying (Behnam)	Surveying Lab: Horizontal and Vertical Angle measurements (Benham)	ACT preparation (Math) Leon
	9:00 - 9:30	Introduction Session to the summer Camp (faculty)				
	9:30 - 10:00	SAET tour (faculty)				ACT preparation (Science) (Leon)
	10:00 - 10:30		Break	Break	Break	
	10:30 - 11:00		Intro to Construction Management & Strength Materials: (Mohamed)	Surveying Lab: Length and Distance Measurement (Behnam)	Soils and Concrete Lab (Benham)	
	11:00 - 11:30					
	11:30 - 12:00					
Lunch	**11:30 - 1:00**	**Lunch**	**Lunch**	**Lunch**	**Lunch**	**Lunch**
Activities	**1:00 - 1:30**	Industry Presentation	Paper Circuits Activity (Tejal)	Intro to Sensors (Tejal)	Intro Robotics (Tejal)	Divide the students into 4 groups (students)
	1:30 - 2:00					
	2:00 - 2:30				Dobot Activity (Tejal)	Jeopardy (Leon)
	2:30 - 3:00	Kahoot Game on CET & EET (Tejal)	AutoCAD Lab (Akinsanya)	Sensors Experiment (Tejal)		Survey
	3:00 - 3:30					
Closing Remarks	**3:30 - 4:00**					**Closing Remarks (Doreen)**

Figure 2. FAMU Engineering Technology Summer Camp Daily Schedule

Camp Class Sessions and Activities

1. *Industry Presentation*: A FAMU alumnus that works as a project manager gave an industry presentation to the students to introduce them to the different opportunities available to

those who graduate from STEM majors. This was particularly helpful since the alum had a similar background to the campers. She offered insights into the career paths and steps necessary to enter the STEM field. The presentation was also an opportunity for the students to ask questions and gain insights into the industry. By the end of the session, the students had a better understanding of the career opportunities available to them once they graduated.

2. *Trivia Games*: The campers were divided into groups to answer STEM trivia questions in electrical/electronics engineering, robotics, and civil and construction engineering. The groups had to work together to answer the questions and test their knowledge in the respective fields. The questions were designed to challenge the campers and help them better understand the topics. After each group finished, the answers were discussed, and the campers had the chance to debate and analyze the solutions. The trivia session was a fun and engaging way for the campers to learn more about STEM topics.
3. *Introduction to Circuits*: The Introduction to Circuits topic was split into two parts, lecture and lab, with the lecture being presented early in the morning and the lab later in the afternoon. During the lecture, the campers were introduced to the basics of electrical circuits and the components that make basic electrical circuits. After the lecture, the campers had the opportunity to work in teams to construct their circuits using provided components and test them to see if they worked. This lab portion of the workshop allowed the campers to apply what they learned in the lecture and gain a deeper understanding of electrical circuits. By the end of the day, the campers had better understood electrical circuits and how they work.
4. *AutoCAD Lab*: The AutoCAD lab activity was designed to introduce the campers to the drawing software AutoCAD. The campers were taught the basics of the software and given a task to draw after they became familiar with it. The campers could practice the different tools available during the lab and create their own drawings. The campers were also able to ask questions and get advice from the instructor. By the end of the lab, the campers better understood the AutoCAD software and the drawing tools available to them.
5. *Surveying*: The faculty instructor introduced engineering surveying to the campers. The students were then guided through a series of activities such as taping, pacing, measuring wheel measurement, automatic level, surveying compass, and theodolite to determine the distances and angles. The activities were completed both inside and around the Banneker buildings. Through this hands-on experience, the campers could better understand how surveying works and the different tools used to measure distances and angles. The activities were engaging and allowed the campers to use their problem-solving skills while learning more about surveying.
6. *Strength of Materials*: The students were taken on a tour of the strength of materials lab. The instructor first explained the importance of studying statics, strength of materials, and structures. Following this introduction, a demonstration of the basic concepts of how to test building materials to know their capacity when loaded under tension, compression, etc., was done. The instructor performed a tensile testing demonstration on two building materials (steel and aluminum) to illustrate to the students how different materials behave under loading. After the demonstration, the campers were allowed to test the materials

independently and better understand how they react to different loads. The Strength of Materials lab was extremely informative and engaging for the campers to learn more about construction management.

7. *Soil Mechanics and Concrete Lab*: The students were introduced to the basic concepts of soil mechanics and concrete technology in the construction soil mechanics and concrete lab. The instructor demonstrated different test equipment and performed the tests in the lab. The soil mechanics lab activities of liquefaction, Torvane shear test, and sieve analysis were all performed. The instructor also tested the compressive strength of concrete for several concrete samples. The campers were able to better understand how soil and concrete behave when subjected to different loads through this lab. The lab activities were engaging and allowed the campers to participate actively in the experiments and learn more about soil mechanics and concrete technology.
8. *Robotics*: The Introduction to Robotics lecture introduced the campers to the basics and applications of robots in various industries. The instructor demonstrated the components of a robot and the different types of robots. After the lecture, the campers worked with a Dobot Magician, a semi-autonomous robot that works with Graphic User Interface (GUI) and python programming to draw different shapes on paper. The campers were able to learn more about robotics through this hands-on experience. They were able to gain a better understanding of the components of a robot and the programming languages used to control it. The Introduction to Robotics lecture and Dobot activity were engaging and informative ways for the campers to learn more about robotics.
9. *ACT Exam Preparation*: The ACT Preparation session was divided into four groups, each receiving a lecture and then taking a mock exam. The lectures covered topics such as time management, strategies for answering questions, and the overall structure of the ACT exam. After the lecture, the campers had the chance to take a mock exam to test their knowledge and practice their time-management skills. The mock exams were designed to challenge the campers and help them prepare for the actual ACT exam. By the end of the session, the campers had gained a better understanding of the ACT exam and the strategies necessary for success on the exam.

Camp Surveys

The study utilized pre- and post-surveys to assess the impact of the summer engineering outreach camps on high school students. The team administered a pre-survey to gauge the level of interest and understanding of the campers before the program began, as well as a post-survey at the end of each day. The surveys included both multiple-choice and open-ended questions designed to assess changes in students' attitudes and perceptions of engineering. The pre-post survey data were used to assess changes in students' attitudes and perceptions of engineering. At the same time, the open-ended responses were analyzed to identify patterns and themes in the data. This approach allowed for a comprehensive evaluation of the camp's impact on the students' understanding and interest in engineering. All the surveys at the camp were conducted using a QR code system, in which students scanned a code using their cell phones to access the survey. This survey distribution method allowed all participants easy and convenient access to the survey.

Based on the daily post-survey data, students overwhelmingly prefer hands-on activities to lecture sessions. Students have voted their favorite activity of the day to be a lab activity 25 times compared to two times for a lecture session, as shown in Figure 3 below. The figure shows the combined votes for the five days of the camp. It is worth noting that the students most disliked lab activity was the surveying lab because they did not like to be outside in the sun as it was hot. The most favorite labs were the circuits and robotics labs. The overall favorite activity in the camp was the trivia games, with eight votes.

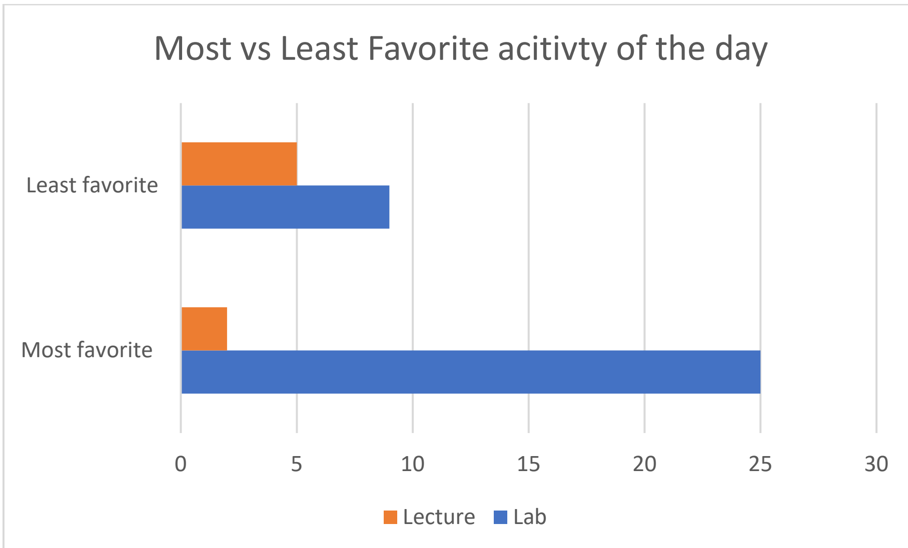

Figure 3. Most vs. Least Favorite Acitivty of The Day

The post-camp survey results indicated that the majority of the students had a positive experience at the Engineering Technology Summer Camp. Over 90% of the students reported that the camp changed their perspective about STEM majors and increased their likelihood of pursuing a career in STEM fields, as shown in Figure 4 and Figure 5. Additionally, students reported that they enjoyed the hands-on, competitive design-oriented engineering projects from various engineering fields.

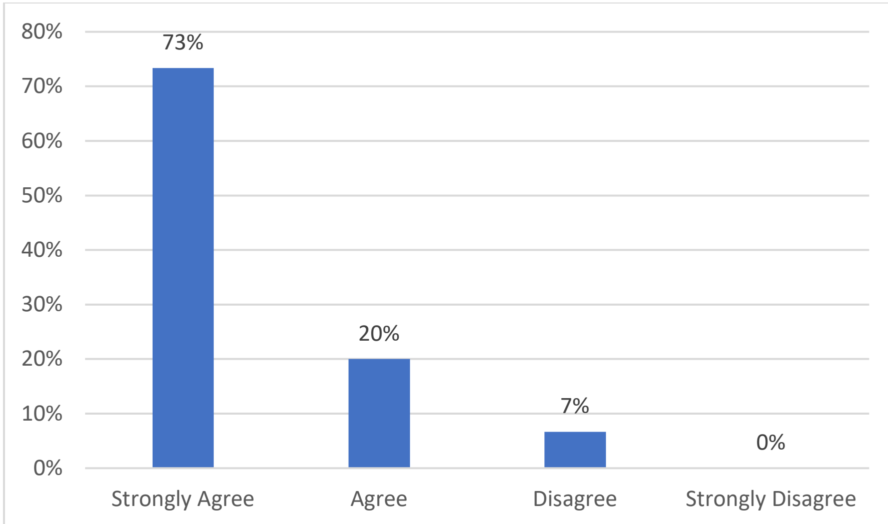

Figure 4. Participation in the Camp Has Changed My Opinion of Engineering

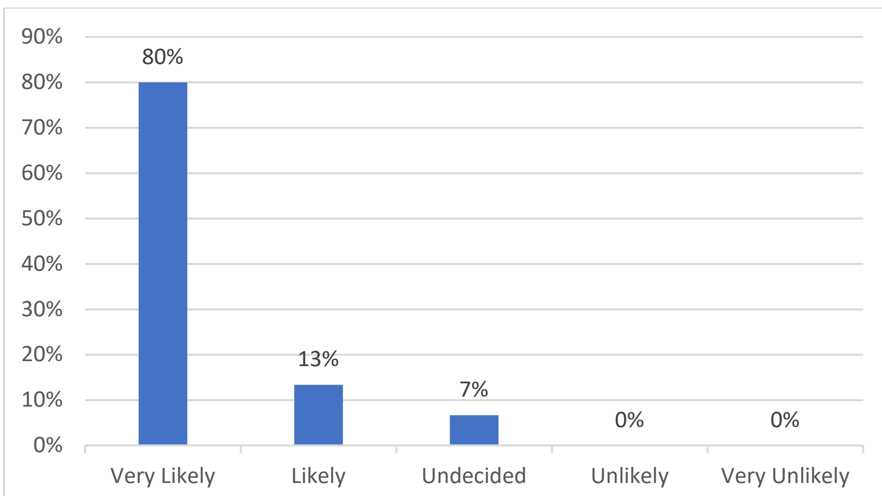

Figure 5. The likelihood that students will consider a STEM career

The survey results also indicate that the camp positively impacted the students' teamwork and oral presentation skills, as demonstrated in Figure 6. The survey also included other questions about how well FAMU's facilities are maintained, to which campers responded positively. Of the respondents, 80% indicated they would likely recommend the summer camp to friends or colleagues. The camp also provided students with valuable information about financial aid, academic programs in STEM offered at FAMU, as well as various career options for prospective engineers. Overall, the survey results demonstrated the effectiveness of the camp in promoting interest and learning in STEM fields among high school students.

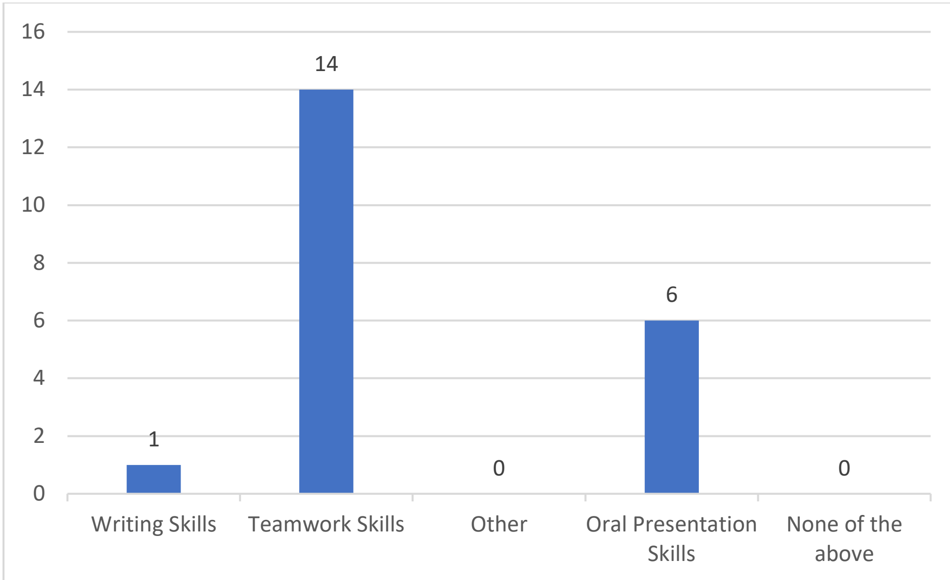

Figure 6. Skills Improved by the Summer Camp

Discussion

The camp surveys indicate that they effectively introduced students to various STEM fields and increased their understanding of available career opportunities. The industry presentation by a FAMU alumnus who works as a project manager was particularly helpful, as the alum offered insight into the career paths and steps necessary to enter the STEM field. The students also reported that the trivia games and hands-on activities, such as the introduction to circuits lab and the AutoCAD lab, were engaging and helped them better understand the topics covered.

The campers also reported that the hands-on activities were engaging and allowed them to apply what they learned from the lectures. The robotics activity and the Strength of Materials lab were particularly effective, as the campers could learn more about robotics and construction management through hands-on experience. The ACT Preparation session was also well-received, with the campers reporting that the mock exams and time management strategies were effective in helping them prepare for the actual test. Overall, the campers reported that the camp was informative and beneficial in assisting them in learning more about STEM fields and the career opportunities available.

Based on the results of the camp surveys, it appears that the students highly valued the hands-on nature of the camp. They particularly enjoyed hands-on activities and team-based activities, such as trivia games. The camp also seems to have helped students improve their teamwork and oral presentation skills. Given these findings, it is clear that hands-on engineering technology summer camps have the potential to be highly effective in attracting underrepresented high school students to STEM majors. Such camps allow students to engage in authentic engineering design experiences and learn about the various careers available in the engineering field. By focusing on hands-on activities and teamwork, these camps can help students develop key skills and gain a deeper understanding of the engineering field.

It is worth noting that the camp surveys are limited in assessing the camp's impact, as they are based on self-report and the sample size was small. Therefore, it is important to conduct followup studies to measure the camp's long-term impact on the students' interest and engagement in STEM fields and include other forms of assessment such as interviews, observations, and testing.

It is recommended that future camps consider incorporating more hands-on activities and team-based activities, and consider implementing measures to address the challenges posed by working outside in hot weather. This may include scheduling outdoor activities during cooler times of day or finding ways to provide shade and hydration. Overall, the results of this study suggest that hands-on engineering technology summer camps are a valuable and effective way to attract underrepresented high school students to STEM majors. By offering students a dynamic and engaging learning environment, these camps have the potential to inspire the next generation of engineers and help diversify the engineering workforce.

Conclusion

In conclusion, the results of the camp surveys indicate that the campers greatly enjoyed the hands-on activities and team-building exercises. They also had a positive response to the trivia games and lectures. However, it was noted that working outside was not a preferred activity, possibly due to the heat.

Based on these findings, the authors recommend that future camps focus on providing more hands-on activities and team-building exercises, as well as incorporating trivia games and lectures. Additionally, it would be beneficial to consider alternative indoor or shaded outdoor spaces for activities to make the camp more comfortable for campers. Furthermore, it is important to note that this camp was intended for underrepresented minorities, and the campers were all Black and African American students. Therefore, we recommend diversifying the pool of campers to include a broader range of underrepresented minorities in order to provide more inclusive and representative experiences for all campers.

Hands-on engineering technology summer camps have the potential to attract underrepresented high school students to STEM majors. These camps provide students with the opportunity to engage in authentic engineering design experiences and learn about the various careers available in the engineering field. The key components of successful hands-on engineering technology summer camps include providing hands-on activities, team-building exercises, trivia games, lectures, and diversity in the camper pool. By incorporating these elements, an enjoyable and informative experience for underrepresented minority students can be attained and encourage them to pursue careers in STEM

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