Impacts of Engineering Summer Camp at East Tennessee State University

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Abstract

The increasing demand for professionals in the fields of Science, Technology, Engineering, and Mathematics (STEM) has created a critical need for effective recruitment strategies to nurture and develop the next generation of STEM talent. Summer camps offer a unique and immersive learning environment that appeals to students of all ages, fostering an interest in STEM subjects while encouraging critical thinking, problem-solving, and teamwork. This paper describes a week-long engineering summer camp program designed for middle and high school students in 2023 at East Tennessee State university (ETSU). The main goal of the camp was to introduce student engineering, programs in the department and job prospects and to spark their interest in pursuing engineering education and career. During the camp students engaged in hands-on learning experiences and featured lessons focusing on 3D scanning, drone technologies, 3D printing, circuitry, robot building, and prototyping. Students also learned about ETSU admission processes, educational programs, financial aid, student organizations and college life. At the end of each day, students completed a survey about their experiences on that day's activities. Data analysis showed that the camp helped students to learn more about what engineers do and made them more inclined to study engineering. This paper presents the effectiveness of the camp's aims, camp planning and design, the results from the participant surveys, and lessons learned by the organizers in conducting the camp. The importance of creating inclusive, diverse, and equitable summer camps is emphasized to ensure that underrepresented groups have equal opportunities in STEM recruitment.

Introduction – A Critical Need of the Engineering Workforce

Engineering talent is in short supply in the US that puts the progress of important industries at risk and threatens to have a negative impact on the US economy [1]–[3]. The Bureau of Labor Statistics data indicates that demand for engineering skills will grow by about 13% from 2023 to 2031 [4], but supply does not meet the demand. Of the total number of students who express an interest in engineering while still in high school, only about 13% complete a university degree in engineering, according to the BCG analysis [5]. Studies have shown that encouraging and maintaining STEM interest throughout a child's education, especially at the middle-school level, is critical to helping fill the talent gap [6]–[7].

The US enjoys a rich heritage of race, gender and ethnic diversity which could contribute to the engineering talent pool, but unfortunately the engineering field has also long struggled from a gender gap and racial equity. Despite significant investment and numerous programs aimed at reducing the gender gap in engineering, just 16% of US engineers are women [8], and the proportion of women among US college graduates in engineering fields has stagnated at around 20% from 2012 to 2022. In addition, Black Americans, Latinxs, Native Americans, and Pacific Islanders are also underrepresented relative to their percentage of the population [9]. Yet, increasing diversity has multiple benefits, including improving the quality of work output and innovation and enlarging the supply of available talent.

To alleviate the shortage of engineers, national and state agencies, professional engineering societies, industry and academia have implemented many strategies at the pre-college level to attract, motivate, stimulate, and educate students in STEM fields. When applied effectively these strategies can produce positive results in addressing the overall deficit problem. Among many established initiatives, effective recruitment tools for STEM majors include: K-12 school outreach, university open house, maker spaces, hands-on career focused workshops, competitions and demonstration, and summer camps [10]. Pingen and Pingen [11] utilized PrintLab as STEM outreach and engaged 5^{th} -12^{th} grade students applying the engineering design method to meaningful projects. Another study showed that holding STEM focused open houses and workshops to let students know what it feels like to engage in science and engineering on a day-to-day basis has increased their knowledge and attitude toward STEM careers [12]. Other studies range from development of a high school-level engineering course to introducing high school students to modern engineering contents, engineering workshop to engineering-based, design-specific robotics competitions [7], [13]–[15].

Strategies using summer camps as a means to introduce pre-college students to STEM disciplines has been successful. Summer camps can promote STEM by engaging hands-on activities and reinforcing learning and/or reducing learning losses of students during the summer months [16]. Studies have shown that STEM camps have many positive outcomes including the promotion of STEM majors, allowing for hands-on learning, reducing the drawbacks of high-school to college transition, and creating new friendships and social skills [17]–[19].

In an effort to mitigate the engineering talent gap that already exists, this paper presents a week-long engineering summer camp program designed for middle and high school students in 2023 at ETSU. The main goal of the camp was to introduce students to the engineering profession and spark their interest in pursuing engineering majors by engaging them in engineering related activities. Students toured our facilities and learned about the programs in the department and potential job prospects. During the camp, students engaged in hands-on learning experiences and featured lessons focusing on 3D scanning, drone technologies, 3D printing, circuitry, robot building, and prototyping. The camp also provided close faculty and student engagement in a laboratory environment to give students a more rigorous, hands-on engineering experience, while problem solving in a college setting. Students also learned about ETSU admission processes, educational programs, financial aid, student organizations and college life. A participant survey was created and administered. Data analysis showed that the summer camp had an effective STEM outreach approach to promote engineering education and to motivate, recruit, and retain potentially promising high school students to engineering disciplines.

A Brief Literature Review of Summer Camps

Historically, summer camp has been an educational vehicle for introducing K-12 students to a variety of educational experiences beyond the classroom [6],[10], [20]. Summer camp is traditionally associated with enjoyable activities and when coupled with the integration of specialized academic matter, can offer students to try new things, explore new programs, engage and learn new knowledge, and broaden their horizon and interests. This intense, but short

sequences, provides an ideal means for the introduction and immersion of K-12 students into areas that might not be easily accomplished in a traditional classroom setting.

Summer camps focusing on various engineering fields have been conducted to introduce students to the engineering profession and have been used successfully as an academic recruiting tool. Studies have shown varying forms of summer camps based on target groups, aims and scope. Some of these camps offer their programs mainly to urban students [21], others for rural [22]. Some are designed for elementary level students [23], or middle and high school students [24 – 25]. Some institutions offered camps that are gender-specific for girls only [26], [27], or target Hispanic high school students and other minority groups [28]. The camp curricula employed in these camps also vary in scope. Some of these curricula might cover a specific engineering topic such as robotics, biomedical applications, rocketry, radio-controlled airplanes, or they might include short activities covering several engineering disciplines [29] – [31]. Irrespective of the nature of the summer camps, findings from most of these programs appear to be highly successful in presenting what engineering entails while motivating the participants to continue the path towards becoming an engineer.

There is much research on the subject of summer camps and their effectiveness. Hammack et al. [24] found a positive impact on participants' attitudes towards engineering based on a middle school summer camp. However, it was not clear which of the camp activities contributed most to this impact. Godwin et al. [25] have examined how high school informal science experiences affect the choice of engineering majors in college and showed that these experiences do affect participants' choice in their chosen major, a topic that has not been the focus of many researchers. Several studies, including those by Elam et al. [32] and Nadelson and Callahan [33], have shown that engineering summer camps do indeed influence how students view engineering, but do not address the topics of interest or identity formation. Although not specific to informal education experiences in engineering, Ing et al. [34] found that it was important for students to be introduced to engineering in their elementary or middle school years.

Planning and Organizing the Camp

The planning of the camp started during the 2023 spring semester with the recruiting of faculty and speakers, and contacting local after school organizations. This was followed by planning camp activities. Our department has a history of conducting summer camps and bringing students (especially underrepresented groups and girls) in the department and exposing them to different programs and lab activities. We leveraged our existing knowledge and resources during the planning process. We marketed the camp through university, college and department newsletters. Since the department has strong relationships with many local organizations such as Boys and Girls Club of JC, Langston Afterschool Institute, Carver Recreation Center, LXI Johnson City and Girls Inc. recruiting students was relatively straightforward. As discussed, earlier minority students, especially white female, African American, Latino, and Native American high school students, traditionally have had little encouragement in pursuing careers related to engineering. As such, we have targeted recruitment to young women, underrepresented and economically disadvantaged students, though the camp was open to all middle and high

school students. Anticipating financial barrier to these groups of students, we made the camp free to all participants through a Tennessee Architecture and Engineering Grant.

Camp Activities

The camp activities were primarily designed to give students a flavor of what engineers do. The first day of the camp was student orientation and a facilities tour. Students learned about different programs in the departments, curriculum, career preparation and job prospects. The remaining four days of the camp involved eight different activities with two activities per day. Day two activities involved 3D Scanning and Drone Technologies. The instructor briefly discussed 3D scanning technology for surveying and mapping, provided a demonstration and let students investigate and analyze a 3D scan of a historic cave. In the second half of the day students were introduced to drone technology, drone architecture, and flying of a drone equipped with a thermal camera to measure the temperature of a building. Students spent day three in the electrical and electronics lab. Students learned about different equipment including a multimeter, oscilloscope, function generator, etc. and later used the equipment to calculate the speed of light. Day four activities involved robotics and 3D Printing. Students learned about robot control and operations and assembled a robot using a kit. In the second half of that day students learned about 3D printing, designed a part in Fusion and 3D printed the part. Students learned about engineering design processes on the last day of the camp. They designed a model, laser cut the parts in plywood, and assembled the parts. Figure 1 shows pictures of students' engagement with various camp activities.

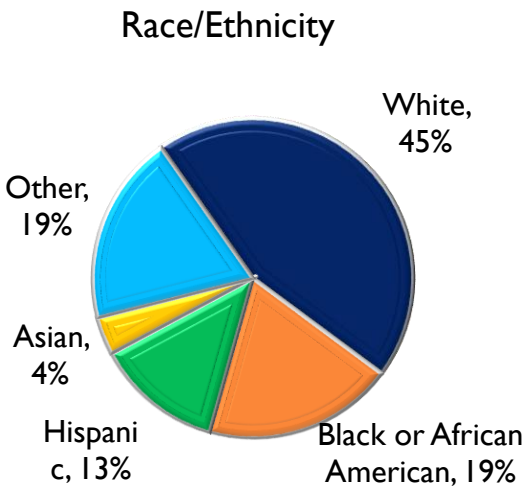
Fig. 1. Camp activities: a) Robot building, b) Measuring speed of light, 3) 3D Printing and 4) Model assembly

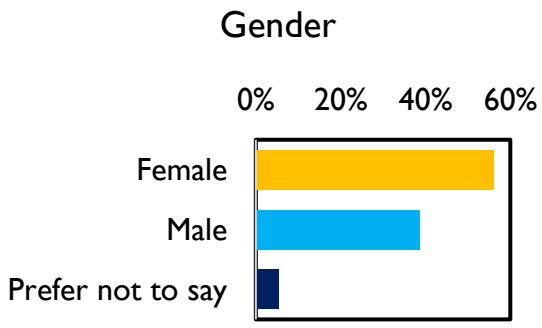
Methodology

For the camp assessment, we developed a survey instrument and administered it at the end of each day during the week of the camp. The goal of the survey was to capture students' understanding/liking/feedback of the activities of that day and analyze several students' characteristics that might be linked to their future career decision-making following participation in the summer camp. The remainder of this paper presents participants' responses to the survey and summarizes relevant descriptive statistics.

Participants

A total of 47 students attended the summer camp. Most of the students who participated in the summer camp were from minority groups (55%). This is encouraging since minority groups are underrepresented in the engineering profession. Among them 19% were African-American, 13% Hispanic, 4% Asian, 19% other and the remaining 45% identified as White (Figure 2). 56% of the campers were female which was also encouraging. The camp was primarily designed for middle and high school students and 83% of the participants were representative of that group. However, 8 participants attended the camp who were below 6th grade. (Figure 2).





	No	Percent
Elementary School	8	17%
Middle School	26	55%
High School	13	28%

Fig. 2. Camp participants' demographics

Data Collection and Results

A participant survey was created in Qualtrics and appropriate IRB approval was secured. The survey consisted of 17 questions focusing on student demographics, their experiences of that day's activity, their interest in math and science, parents' education, and college preparation. Each student was required to complete the survey, which resulted in a 100% response rate. After the camp was completed, data were analyzed and summary statistics were created.

Student Engagement with the Summer Camp Projects

In the daily survey, students were asked about learning of the daily activities. A word cloud was created based on the students' response as shown in Figure 3. Light speed, 3D printing, robot, drone, build, design, and model were frequently mentioned which was aligned with daily

activities. Whether working in an individual or group project, students were engaged and pleased with the work they produced.

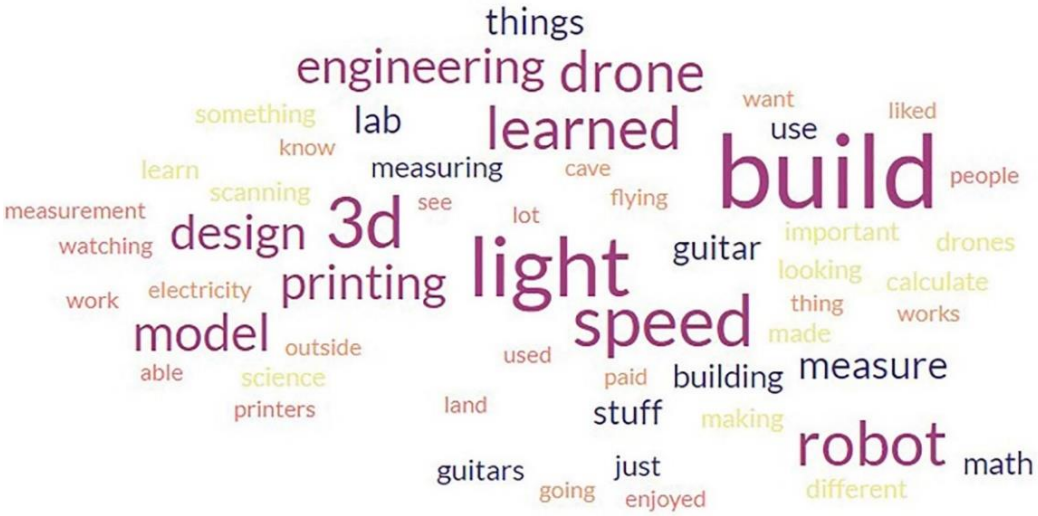


Fig. 3. Word cloud of student learning of daily activities.

Understanding of Engineering Profession

Research shows that interest in STEM occupations has been linked to students' knowledge of STEM careers [6]. In response to the question "what do engineers do?" it seemed the students had a limited understanding of the profession of engineering. Students were given six prominent activities that engineers typically perform. They are "design, build, and test", "come up with creative solutions", "develop new products, services, technologies and processes", "analyze data", "apply math and science", and "help society" (Figure 4). We expected that students would choose all six activities, but almost half of the students selected only one: "design, build, and test," "come up with creative solutions," or develop new products, services,

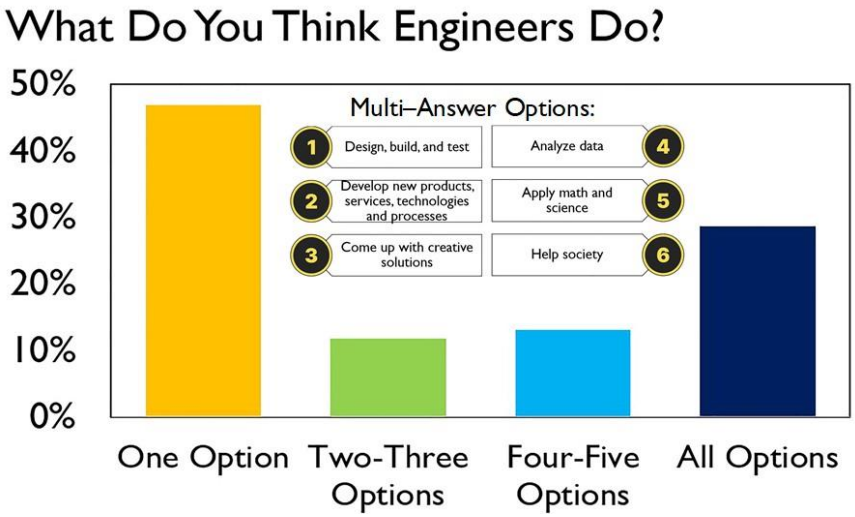


Fig. 4. Distribution of student responses to the question "What do you think engineers do?"

technologies and processes." Only 27% of students selected all six activities. The lack of students entering engineering programs may be attributable to a lack of understanding of what type of work engineers perform. There are numerous engineering and technology career options available and we need to clearly communicate and introduce engineering professions to K-12 students to make them more interested about engineering.

Math and Science Interest

Students were asked if they like math and science and 75% of students reported that they enjoy their math and science classes (Figure 5). Intuitively, 80% of these students also mentioned they have already taken or are planning to take one or more engineering related courses (such as CAD, Robotics, Construction, etc.) in their schools compared to 20% of students who reported that they don't like math and science. Similarly, students who reported they like math and sciences are also more engaged. 80% of them mentioned that they have joined a school club. Interestingly, 78% of students who reported that they like math and science also reported that they are interested in attending college compared to 22% who reported that they don't like math and science. It is probable that students' interest in math and science is an indicator of students' interest in pursuing STEM careers. Therefore, parents and teachers need to introduce children to STEM fields during early childhood which may over the time entice more students toward engineering.

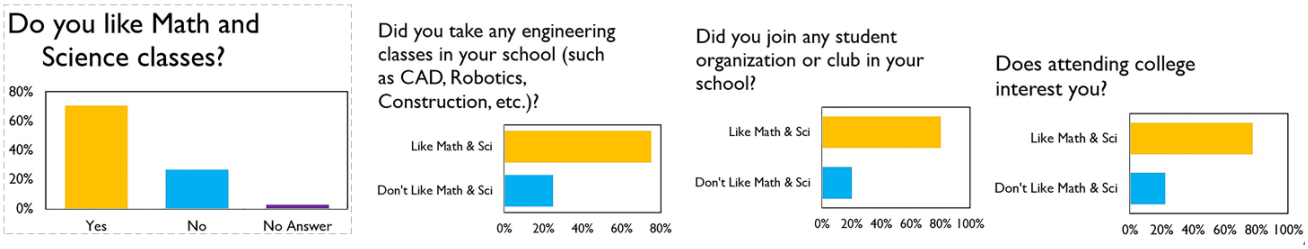


Fig. 5. Comparison of students who like or don't like math and sciences towards attending college.

Parent's Education

Parents influence children's education. Children whose parents engage them in activities or conversations on scientific topics, foster a home environment that values STEM, and thereby ingrain relevant values, attitudes, and academic work habits required to succeed in STEM fields are more likely to choose and persist in a STEM major [35]–[36]. In the survey, students were asked if either of their parents attended college and 80% of the students reported yes. It seems these parents encourage their children to participate in math and science-focused extracurricular activities. This is because our results show a significantly higher number of students (whose parents attended college) like math and sciences, have taken, or plan to take, engineering-related courses in high school and are four times more likely to attend college compared to those whose parents did not attend college (Figure 6). This suggests that parents' levels of education along with other factors are more likely to provide many opportunities for their children to learn both inside and outside of school, which helps to increase their STEM interest and success.

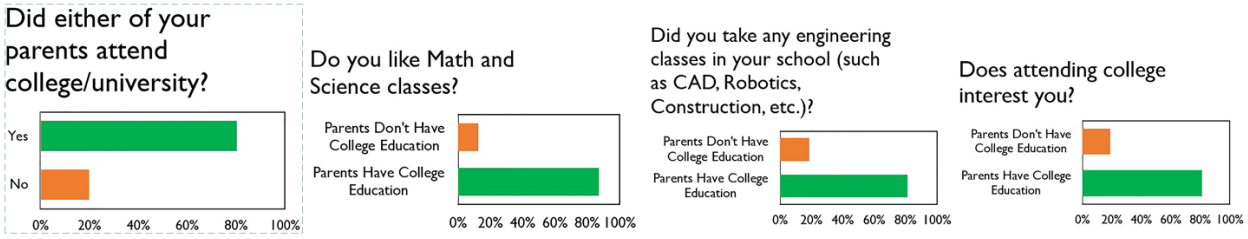


Fig. 6. Comparison of parents' levels of education toward participants' intention to attend college.

Effectiveness of the Camp and Pre-College Student Support

Analysis of student feedback revealed that they enjoyed the camp activities, which provided them better a understanding of the engineering profession. More than 80% of the students mentioned that the camp made them more inclined to study engineering (Figure 7). However, they also identified several areas where they needed help. Most students reported that they need significant help with admissions, financial aid, and scholarships. These are followed by career preparation and extra-curricular activities that they are interested to pursue in college. A wrap around support system involving parents, K-12 educators, counselors, and higher education entities need to fill in the gaps and provide knowledge, services, and confidence needed for more students to pursue engineering.

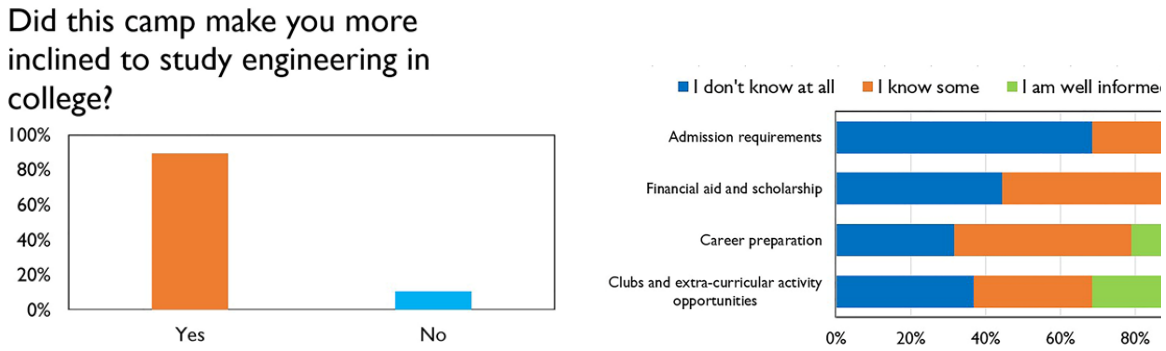


Fig. 7. ETSU summer camp effectiveness and prospective students support needs.

Conclusions

Engineering Summer Camp at ETSU was a success. Results show that camp activities were effective in triggering students' engineering interests. Several lessons were learned by organizing the camp. First, planning and logistics for summer camp take time and can be complicated. Early planning, shared responsibility, and having clear communication with all stakeholders can make running the camp smoother. Technology can fail and disrupt planned activities. Having backup and/or additional activities keeps students engaged throughout the day. Lastly, engaging parents with various college preparation and support systems will remove barriers for an easier transition of high school students to college. Early STEM Awareness, engaging STEM activities, and providing opportunities to build engineering identity, can alleviate the engineer shortage in the US.

References

[1] K. Squires, "America needs more engineers," 2023. [Online]. Available: https://engineering.asu.edu/convergence2019/coming-soon-a-shortage-of-engineers/.

[2] R. L. Reid, "Why US civil engineering firms face a labor shortage," Civil Engineering Magazine, 2023. [Online]. Available: https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/issues/magazine-issue/article/2023/05/why-us-civil-engineering-firms-face-a-labor-shortage.

[3] C. J. Maker, "Identifying exceptional talent in science, technology, engineering, and mathematics: Increasing diversity and assessing creative problem-solving," *Journal of Advanced Academics,* vol. 31, p. 161–210, 2020.

[4] E. Torpey, "Engineers: Employment, pay, and outlook," 2023. [Online]. Available: https://www.bls.gov/careeroutlook/2018/article/engineers.htm.

[5] A. Kodey, J. Bedard, J. Nipper, N. Post, S. Lovett and A. Negreros, "The US Needs More Engineers. What's the Solution?," Boston Consulting Group, Boston, MA, 2023.

[6] T. Robinson, A. Kirn, J. Amos and I. Chatterjee, "The Effects of Engineering Summer Camps on Middle and High School Students' Engineering Interest and Identity Formation: A Multi-methods Study," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 13, p. 6, 2023.

[7] L. Chu, V. Sampson, T. L. Hutner, S. Rivale, R. H. Crawford, C. L. Baze and H. S. Brooks, "Argument-Driven Engineering in Middle School Science: An Exploratory Study of Changes in Engineering Identity Over an Academic Year," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 9, October 2019.

[8] A. Martinez and C. Christnacht, "Women Are Nearly Half of U.S. Workforce but Only 27% of STEM Workers," The US Census Bureau, Wasington, D.C., 2021.

[9] A. Okrent and A. Burke, "The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers," National Science Foundation, Washington, D.C., 2021.

[10] K. J. Krapcho and C. Furse, "Lessons learned developing an engaging Engineering Summer Camp," in *2014 ASEE Annual Conference & Exposition*, 2014.

[11] G. Pingen and B. Pingen, "Going Deeper in Engineering K-12 Outreach: Assistive Technology Projects," in *ASEE Southeast Section Conference*, 2023.

[12] K. Marchocki, "Promising practices in outreach, recruitment for STEM," 2023. [Online]. Available: https://www.ccdaily.com/2023/11/promising-practices-in-outreach-recruitment-for-stem/.

[13] J. R. Grohs, A. L. Gillen, H. M. Matusovich, G. R. Kirk, H. L. Lesko, J. Brantley and C. Carrico, "Building Community Capacity for Integrating Engineering in Rural Middle School Science Classrooms.," *Journal of STEM Outreach,* vol. 3, p. n1, 2020.

[14] R. Canek, P. Torres and O. Rodas, "Encouraging higher education stem careers through robotics competitions," in *2020 IEEE Integrated STEM Education Conference (ISEC),* 2020.

[15] S. Anwar, N. A. Bascou, M. Menekse and A. Kardgar, "A systematic review of studies on educational robotics," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 9, p. 2, 2019.

[16] T. Shepard and C. T. Altobell, "Engineering in Summer Camps: Tapping the Potential," in *2012 ASEE Annual Conference & Exposition*, 2012.

[17] C. Maiorca, T. Roberts, C. Jackson, S. Bush, A. Delaney, M. J. Mohr-Schroeder and S. Y. Soledad, "Informal learning environments and impact on interest in STEM careers," *International Journal of Science and Mathematics Education,* vol. 19, p. 45–64, 2021.

[18] H. A. Ochoa, C. J. Aul, D. Bruton and C. J. Timmons, "A Summer Camp in Engineering Physics for Incoming Freshman to Improve Retention and Student Success," 2017.

[19] K. Gray and S. Coffman-Wolph, "Evaluation of the Impact of a Summer STEM program on Participant's Perception and Knowledge of STEM Careers (Evaluation)," in *2017 ASEE Annual Conference & Exposition*, 2017.

[20] M. Yilmaz, J. Ren, S. Custer and J. Coleman, "Hands-on summer camp to attract K–12 students to engineering fields," *IEEE transactions on education,* vol. 53, p. 144–151, 2009.

[21] K. J. Newton, J. Leonard, A. Buss, C. G. Wright and J. Barnes-Johnson, "Informal STEM: Learning with robotics and game design in an urban context," *Journal of Research on Technology in Education,* vol. 52, p. 129–147, 2020.

[22] B. L. Donham and M. Elam, "Promoting interest in engineering in rural school districts through summer camps," in *2010 GSW*, 2022.

[23] D. Gossen, R. Hammack and J. Utley, "Impact of a summer camp on elementary students' understanding and awareness of engineering careers and attitudes toward engineering," *The Electronic Journal for Research in Science & Mathematics Education,* vol. 25, p. 23–41, 2021.

[24] 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, p. 2, 2015.

[25] A. Godwin, G. Sonnert and P. M. Sadler, "Disciplinary differences in out-of-school high school science experiences and influence on students' engineering choices," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 6, p. 2, 2016.

[26] K. M. Braswell, J. Johnson, B. Brown and J. Payton, "Pivoting during a pandemic: Designing a virtual summer camp to increase confidence of black and latina girls," in *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, 2021.

[27] M. R. Schilling and M. Pinnell, "The STEM gender gap: An evaluation of the efficacy of women in engineering camps," in *2018 ASEE Annual Conference & Exposition*, 2018.

[28] A. Martinez Ortiz, L. Rodriguez Amaya, H. Kawaguchi Warshauer, S. Garcia Torres, E. Scanlon and M. Pruett, "They choose to attend academic summer camps? A mixed methods study exploring the impact of a NASA academic summer pre-engineering camp on middle school students in a Latino community," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 8, p. 3, 2018.

[29] K. Ney, "Designing a Week-Long Biomedical Engineering Summer Camp to Increase Young Students' Interest and Self-Efficacy in STEM," 2020.

[30] A. Tekbiyik, D. Baran Bulut and Y. Sandalci, "Effects of a Summer Robotics Camp on Students' STEM Career Interest and Knowledge Structure.," *Journal of Pedagogical Research,* vol. 6, p. 91–109, 2022.

[31] H. Stroud and K. J. Shryock, "Hands-on Exposure to Unconventional Applications of Aerospace at the High School Level," in *2019 ASEE Annual Conference & Exposition*, 2019.

[32] M. Elam, B. Donham and S. R. Soloman, "An engineering summer camp for underrepresented students from rural school districts," *Journal of STEM Education: Innovations and Research,* vol. 13, 2012.

[33] L. S. Nadelson and J. M. Callahan, "A comparison of two engineering outreach programs for adolescents," *Journal of STEM Education: Innovation and Outreach,* 2011.

[34] P. R. Aschbacher, S. M. Tsai, "Gender differences in the consistency of middle school students' interest in engineering and science careers," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 4, p. 2, 2014.

[35] N. Tilbrook and D. Shifrer, "Field-specific cultural capital and persistence in college majors," *Social Science Research,* vol. 103, p. 102654, March 2022.

[36] Z. H. Wan, Y. Jiang and Y. Zhan, "STEM education in early childhood: A review of empirical studies," *Early Education and Development,* vol. 32, p. 940–962, 2021.