Using Experiential and Collaborative Learning to promote Careers in Engineering

Rochelle Williams[2], Sherri Frizell[1], Felecia Nave[1,2] and Audie Thompson[1]

[1]Roy G. Perry College of Engineering, [2]Academic Affairs, Prairie View A&M University
700 University Drive, Prairie View, TX, 77446, USA
E-mail: akthompson@pvamu.edu, ssfrizell@pvamu.edu, rlwilliams@pvamu.edu, fmnave@pvamu.edu

Abstract

This paper discusses the design of the Girls Accelerating and Learning STEM (G.A.L.S.) one-week residential summer camp designed to encourage young girls to pursue engineering careers. Specifically, the camp exposed participants to the fields of computer science and engineering using experiential learning to develop participant interest and skills. At the end of the program, students participated in team competitions and presented their work. The end-of-program survey data showed that the G.A.L.S. camp had an impact on the enhancement of student interest in engineering as a potential career. The paper will provide details on the program components, and further discuss the impacts of the program and how it can be used as a model for future programs.

1. Introduction

Gender disparities in STEM interest and achievement have narrowed, but females are still less likely to enter and remain in STEM careers [1] despite data indicating that girls in high school attempt a similar number of advanced mathematics courses as boys [2,3]. Additionally, achievement gaps along racial lines continue to persist, particularly for black and Hispanic students [4]. Although women continue to make a great impact in engineering fields, they continue to be significantly underrepresented in the U.S. STEM workforce [5]. This trend is often attributed to the low number of women who pursue STEM majors in college, low self-efficacy in STEM-related courses, and/or feelings of discouragement to enter a male-dominated workforce [6]. Nationally, both educational and scientific communities are focusing resources on increasing the STEM workforce. Such efforts have included engaging students during the summertime. According to the National Summer Learning Association [7], high-quality summer programs have shown to improve math and reading skills, as well as increase graduation rates and success in higher education. In particular, summer programs with a focus on STEM offer a multi-faceted opportunity to maintain and build core skills in math during the critical summer months [7].

In an effort to increase the number of girls of color interested in pursuing STEM careers, an outreach summer program was created at Prairie View A&M University (PVAMU), an Historically Black College & University in Texas, to enlighten girls from underrepresented populations in STEM on how enjoyable, rewarding, and beneficial careers that utilize science, technology, engineering, and mathematics can be. The Girls Accelerating and Learning STEM (G.A.L.S.) camp was designed to expose high school girls to computer science and engineering to develop their interest and skills through experiential learning. The program's objective was three-fold: (1) to expose girls to fundamental concepts in engineering and computer science, (2) to guide participants toward careers in engineering fields by facilitating access to same-sex visible figures in academia and industry, and (3) to educate both parents and students about the college application and scholarship process particularly at PVAMU. This one-week residential program for 20 rising 9th through 11th grade girls aimed to positively reinforce or spark participant interest in pursuing an engineering or computer science career. Understanding the role visible figures play in the pursuit of a STEM degree, camp activities were led by women engineering and computing faculty at PVAMU, women students from undergraduate STEM organizations, and women guest speakers from industry. The importance of same-sex role models, or visible figures, in STEM careers is critical. Girls/women who are exposed to successful women in STEM fields are more likely to do well in STEM classes, feel a greater sense of belonging among their STEM classmates and colleagues, and are more likely to have career aspirations geared towards science [8,9,10]. When women see other women in science, math, technology, and medical fields, they are less likely to associate these fields with masculinity and more likely to have confidence in their own skills [8].

Camp participants were recruited from schools within and outside the city of Houston, Texas. Guidance

counselors at local area high schools were sent promotional materials, and the program was advertised on the University's website and other social media platforms. The most effective advertisement resulted from word-of-mouth promotion by PVAMU alumni. A particular focus was on Region 4 high schools in Houston, Texas that have a memorandum of understanding (MOU) with PVAMU. Statistically, 58.2 percent of the students in Region 4 schools are categorized as "economically disadvantaged" (i.e. receive free or reduced meals) and 69.6 percent are from underrepresented ethnic groups in STEM. Thus, priority acceptance was given to high school girls from one of the 17 Region 4 high schools.

To apply for the program, students were required to submit an application, an essay that discussed their interest in STEM, a copy of their transcript, and a recommendation letter from a teacher. To further broaden the pool of participants, the program leaders assessed the ***perceived benefit*** of attending the G.A.L.S. camp for each applicant. The following items were taken into consideration in assessing perceived benefit:

- Students who identified factors that most influenced their future career plans that aligned with the objectives of the camp
- Students who had misconceptions about the role STEM could play in their future career decisions
- In the spirit of PVAMU's mission &history, students who may not have a strong academic record, but who could greatly benefit from participating in the camp

Twenty students were selected to participate with 95% of the accepted participants identifying as African-American. The program fee was $50 so that financial limitations would not prevent students from participating.

2. G.A.L.S Program Structure

Women faculty and staff in the College of Engineering at PVAMU led the G.A.L.S. Camp. Although the daily lessons were different, each day the girls were exposed to fundamental concepts in engineering and computer science through hands-on projects and lectures. The G.A.L.S camp provided the participants with an opportunity to develop both their technical and professional skills. In teams of four, participants worked on different engineering projects. This included: 3-D printing model rocket parts, building and launching a model rocket, building a ChemE car, building and testing a popsicle bridge, building and testing a payload for an egg drop competition, building a rolling robot, and designing an app. To further develop teamwork and communication skills, participants gave oral presentations on each group project.

Discipline specific camp activities were based on the expertise of faculty leads, and each activity required participants to journal about not only what they learned that day, but also consider the broader impacts of that activity on society. Projects focused on five areas of engineering (chemical, civil, computer and electrical engineer, mechanical) and computer science.

The ***mechanical engineering project*** focused on the intersection of materials science, engineering and model rocketry. Participants had to consider rocket materials, forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. Students worked in teams under faculty supervision to 3D print, construct, and launch a rocket. After completing the activity, students were able to explain the importance of material selection in the engineering design process, determine what measuring tool and units to use in constructing a model rocket, and demonstrate fundamental knowledge about 3D printing. Additionally, students used the fundamental principles of physics to design a payload that would protect an egg at 10ft and 30ft. The students learned that Mechanical Engineers use material composition, weight capacity and effects of impact when designing and making instruments, tools and vehicles.

Participants were exposed to bridge design during the ***civil engineering project*** on day 2. This lesson focused on how bridges are engineered to withstand weight, while being durable, and in some cases aesthetically pleasing. Students worked in teams to design and build a bridge out of up to 200 popsicle sticks and glue. Bridges were required to have a span of at least 14 inches and hold a five-pound weight (9^{th}-10 graders) or a twenty-pound weight (11^{th} graders). Students were encouraged to be frugal, and use the fewest number of wooden sticks, while still achieving their goals. As a result of this activity, students developed an understanding of structural engineering and design, and planning, construction, and problem solving.

The projects in ***computer and electrical engineering*** were spread across 2 days and focused on programming Arduino based robotics and building a rolling robot with a BASIC Stamp 2 microcontroller brain. Participants gained experience with programming, circuits, sensors, and hardware. The activity required wiring and source code tuning. After completing the activity, students could write simple code using basic programming tools, read simple circuit diagrams and construct circuits on a breadboard, explain why systems often do not behave as predicted, and explain how even carefully constructed code can mitigate uncertainty in system behavior.

The objective of the ***computer science project*** was to expose students to the discipline of computer science and engage them in software development activities using beginner-friendly tools for mobile application and game development. In one of the activities, students designed an

app using MIT App Inventor. After completing the activities, students were able to demonstrate a broad understanding of software development, design a solution to a computing problem, and use programming tools to develop computer applications.

The final project on the last day of camp focused on a ***chemical engineering*** activity, the Chem-E-Car. This lesson focused on polarization, reaction rates, reversible electrolysis reactions and renewable energy through creating fuel cell and solar cars. The participants explored how hydrogen is used to power the fuel cell car and alternative energy to power solar cars. Participants experimented with how changing angle, adding weight, incline and decline affect motion and energy requirements. At the conclusion of the program, students launched their group rockets built on day one and had a Chem-E Car competition. The competition was judged by a group of Chemical Engineering Faculty and a representative from Chemstations, Inc. To improve the students' oral presentation skills, teamwork and leadership skills, the participants had to present their cars and explain the reaction and reasons for movement. After the competition, the judges served as panelist and shared their educational experiences and perspectives from industry and academia. Including a competition required the students to work more as a team. Students who were usually introverts participated more to make sure their team won. They also paid more attention to detail to make their car operate properly.

The second objective of the camp was to guide participants toward careers in engineering fields by facilitating access to same-sex visible figures not only in academia, but also industry. Participants toured the General Electric facility in Houston, TX. They had the opportunity to ask a panel of women engineers about "a day in the life of an engineer." Additionally, the panelist led the students on a supply chain activity to help the students gain a better understanding of the different jobs you can do as an engineer. In addition to the industry tour, participants heard from a panel of Chemical Engineering professionals about life in industry as a chemical engineer. An opportunity to encounter female professionals allowed the girls to visualize themselves in these prominent STEM professions. As expected the participants were more excited in the industry setting than the classrooms/lab. During lunch, they were able to interact with them in a more personal manner. The visible figures of these women engineers solidified some of their ambition to become an engineer. For those who were not interested in engineering, the experience gave them examples of leaders in industry. Thereby, increasing their confidence in their chosen career. After the tour, the participants were taken to Kemah Boardwalk Amusement park. The fun activity allowed the students to bond more and gain an understanding of work life harmony. Some students noted that this was the most enjoyable part of the camp.

The final component of the summer program was to educate both parents and students about the college application and scholarship process at PVAMU. The effect of parental involvement on academic success especially for minority students is well documented [11,12]. On the last day of the program, parents attended an information session on the apply Texas application process, financial aid, and scholarship opportunities at PVAMU.

3. Program Results and Discussion

Pre-and-post surveys were used to assess the effectiveness of the program. Data showed that the G.A.L.S. camp had at a minimum, some impact on the enhancement of student interest in engineering as a potential career. Along with the overall satisfaction of the program, the post survey assessed the extent to which the following helped participants better understand what it's like to be an engineer:

- teamwork
- working on a project presentation
- fields trips or industry site visits
- discussions with professional engineers and scientists

The frequency of responses for those questions are shown in figure 1. Notably, the industry site visit and discussions with professional engineers had the greatest influence on helping participants gain a better understanding of engineering.

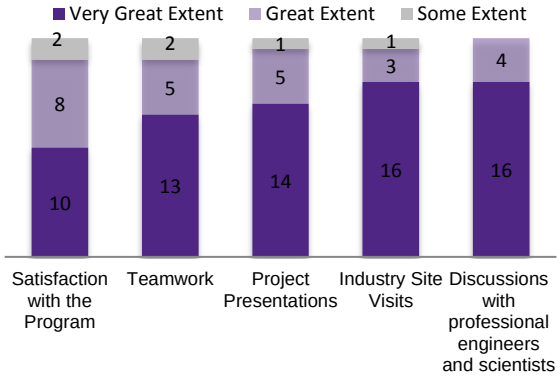

Fig. 1: Frequency of responses to program questions

Additionally, 95% of program participants indicated participating in the program had encouraged them to go to college, and 80% indicated the program had encouraged them to become an engineer. Scores from similar items on both the pre-and-post surveys were also analyzed to

determine change. The items are listed in table 1 and average participant responses are shown in figure 2.

Table 1: Pre-and-post (PP) survey questions

Item	Statement
PP1	I plan to go to college when I finish high school
PP2	My parents/guardians are encouraging me to go to college
PP3	My friends plan on going to college
PP4	I enjoy school
PP5	My teacher(s)/counselor(s) care if I go to college
PP6	I am interested in a specific college(s)
PP7	I have a specific career goal
PP8	I am interested in a career in engineering

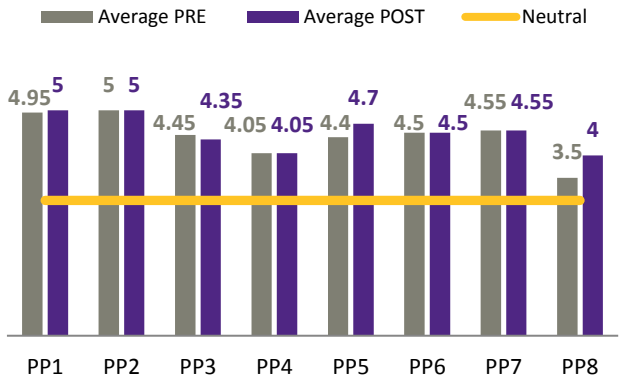

Fig. 2: Responses to Pre-and-post questions

Item PP4, *I enjoy school*, had a low level of agreement (4.05) in both the pre-survey and end-of-program survey. However, when comparing this to responses in question 14 in the end-of-program, *participating in the engineering summer program) has encouraged me to go to college* (4.65), we see the positive affect this type of program can have on students.

Item PP3, *my friends plan on going to college*, also had a lower level of agreement for this data set (4.45/4.35). However, item 16, *I would recommend the program to my friends* (4.8), had the strongest average agreement in the end-of program survey. This demonstrates the broader impact this program can have of young ladies not planning to attend college.

The largest average increase from pre-and-post survey responses was item PP8, "I am interested in a career in engineering", which went from an average response of "neutral/not sure" to "agree" (3.5 to 4). Further analysis of the survey data showed that for seven of the twenty girls, the program reinforced their career goals to become an engineer. The pre-survey asked students to specify their career goals. Students who listed an engineering field were given a "1," students who stated they weren't sure were given a "0" and students who stated a field other than engineering were given a "-1." This was then compared to the individual responses to end-of-program items PP8 and 15, *I am interested in a career in engineering* and *participating in the ESP has encouraged me to become an engineer*, respectively. Because these two items were on a 5-point Likert scale, the responses were coded to align with responses to the open-ended question about career goals, where strongly agree or agree= 1, neutral/not sure = 0, and disagree or strongly disagree = -1 (see Figure 3).

First, the **specific career goal** for each student was plotted, as denoted by the yellow diamond in figure 3. For example, during the pre-survey, GAL1 did not specify a career in engineering, GAL7 stated she was unsure about a career in engineering, and GAL19 specified she would be pursuing a career in engineering. Then, responses to end-of-program items PP8 and 15 were plotted. Continuing from the previous example, GAL1 is not interested in a career in engineering (no purple bar), but the program encouraged her to become an engineer. Similarly, GAL7, who was originally unsure about being an engineer, is interested in a career in engineering and was encouraged by the program.

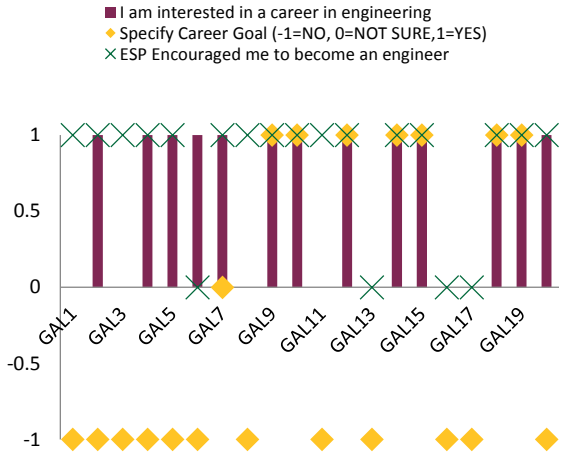

Fig. 3: Career choice and decision to pursue engineering

For seven of the twenty girls, the G.A.L.S. camp reinforced their career goals to become an engineer. Although three of the twenty girls showed no interest in engineering as a result of the program, four were not only encouraged to become an engineer as a result of participating in the program, but their interest in engineering was also sparked. Three participants responded they were unsure if they were interested in engineering as a career, but the G.A.L.S. Camp did encourage them to become an engineer. Even though some participants did not gain an interest in engineering, the program received feedback that will aid in the continuous improvement of the

program. Below are examples of comments received from program participants:

> "I learned how engineering can be fun."
> "After learning about alternative energy, I realized how diverse chemical engineering is."
> "After seeing so many African American engineers at GE, I know that I can become an engineer."
> "Either extend the program or do less projects so we can spend more time on them"
> "I thought we would have more fun activities during the day, but it was all work."

4. Conclusion

Exposing high school girls to engineering and computer science supports the growth of the STEM workforce through curricula, outreach, and professional development initiatives. The results from the G.A.L.S. camp show that high school girls from underrepresented groups have an interest in STEM careers. Utilizing women faculty from engineering supported the development of well-designed projects that proved to be challenging, yet engaging and achievable for camp participants. Exposure to same-sex figures both in academia and industry helped participants to see themselves in these roles. Notably, the industry site visit and discussions with professional engineers had the greatest influence on participant's understanding of what it's like to be an engineer. For several of the girls, the program reinforced their career goals to become an engineer. For others, it sparked an interest that wasn't there prior to the camp. The focus of the camp is to introduce female high school students to engineering in a fun and exciting manner. Even though some of the campers indicated they would pursue an engineering career, the camp accomplished its goal by exposing the students to engineering. Although campers may decide against a career in engineering, the camp provided valuable knowledge about engineering and the available career opportunities. This allows campers to share their knowledge of and experiences with engineering with their peers in their community and schools. By campers sharing information, the camp's goal of exposing students to engineering is continuously being met.

Additionally, including journaling as an activity helped the participants to see the societal connections to the STEM problems they worked on. The general reaction to the camp was overwhelmingly positive with many participants expressing a desire to return for a second year. The interest to participate from both parents and girls highlights the continued need for such programs. Even though the group developed friendships during the learning activities, they enjoyed bowling and the amusement park the most. It was noted that more extracurricular activities should be included in the future to emphasize the importance of work life harmony. This is especially true for women in STEM.

Acknowledgement

This work was performed as an Engineering Summer Program funded by the Texas Higher Education Coordinating Board with additional support from the PVAMU Office of Academic Affairs.

References

[1] Anna Beninger. High Potentials in Tech-Intensive Industries: The Gender Divide in Business Roles (Catalyst, 2014).

[2] Choi, Namok, and Mido Chang. "Interplay among school climate, gender, attitude toward mathematics, and mathematics performance of middle school students." Middle Grades Research Journal, vol. 6, no. 1, 2011, p. 15+. Academic OneFile, Accessed 21 Jan. 2018.

[3] Hyde JS, Lindberg SM, Linn MC, Ellis AB, Williams CC. Gender similarities characterize math performance. Science. 2008; 321:494–495.

[4] Riegle-Crumb, C., Moore, C. & Ramos-Wada, A. (2011). Who wants to have a career in science or math?: Exploring adolescents' future aspirations by gender and race/ethnicity.. Science Education, 95(3), 458–476.

[5] Ryan Noonan. Women in STEM: 2017 Update (US Department of Commerce, Economics and Statistics Administration, Office of the Chief Economist, November 13,2017

[6] National Center for Education Statistics, "Table 318.30: Bachelor's, Master's, and Doctor's Degrees Conferred by Postsecondary Institutions, By Sex of Student and Discipline Division: 2014-15," Digest of Education Statistics: 2016 Tables and Figures (2017)

[7] National Summer Learning Association. STEM in the Summer: The Joy of Meaningful Learning. Retrieved from: http://www.summerlearning.org/wp-content/uploads/2016/10/STEM-in-Summer_keyline.pdf

[8] Danielle Young, Laurie Rudman, Helen Buettner, and Meghan Mclean. 2013. "The Influence of Female Role Models on Women's Implicit Science Cognitions." Psychology of Women Quarterly 37(3): 283-292.

[9] Lisa Rosenthal, Sheri Levy, Bonita London, Marci Lobel, and Carney Bazile. 2013. "In Pursuit of the MD: The Impact of Role Models, Identity Compatibility, and Belonging Among Undergraduate Women." Sex Roles: A Journal of Research 68(7-8): 464-473.

[10] David Marx and Jasmin Roman. 2002. "Female Role Models: Protecting Women's Math Test Performance." Personality & Social Psychology Bulletin 28(9): 1183 -

1194.
[11] Lewis, C., Bonner, F., Rice, D., Cook, H., Alfred, M., Nave, F., & Frizell, S. (2011). African American, Academically Gifted, Millennial Students in STEM disciplines at Historically Black Colleges & Universities (HBCUs): Factors that Impact Successful Degree Completion. In H. Frierson & W. Tate (Eds)., Beyond Stock Stories and Folktales: African Americans' Paths to STEM Fields, vol.11, pg. 23-46. Emerald Group Publishing.
[12] Bonner, F., Alfred, M., Lewis, C, Nave, F., & Frizell, S. (2009). Historically Black Colleges and Universities (HBCUs) and Academically Gifted Black Students in Science, Technology, Engineering, and Mathematics (STEM): Discovering the Alchemy for Success. Journal of Urban Education: Focus on Enrichment, 6(1), pp. 122-136.