Girl Scouts: Students Who Engineer Magic

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Careers in engineering help a person to both contribute toward solving problems in society and environment and live independently with available work. Nevertheless, a disproportionate number of females have not entered careers in engineering. One factor for the low participation may be insufficient exposure to compelling engineering activities at an early age. As a response, many educators and activists have initiated STEM activities for younger women to engage in, and potentially increase their interest and likelihood to pursue engineering pathways. One example is a STEM Day for Girl Scouts that has been organized at our university for several years. Girl Scouts STEM Day is a program to help 4th or 5th grade students explore STEM activities and learn about some of the engineering fields. The event first started at our university in 2014 with 30 students and has grown to 96 before COVID, there are 57 participated the STEM activity in 2024. Since 2014, around 600 girl scouts have participated in the skills-based workshops and hands-on projects.

The one-day program started with a team building, active experience followed by inspiring speeches by women leaders in their careers. Then the students break into small groups and rotate through five different STEM workshops: Biological Engineering, Biomedical Engineering, Electrical Engineering, Manufacturing, and Computer Science. There was about forty-five minutes for each workshop. Descriptions and observations of the five workshops are presented in this paper. The Biological Engineering project was low-cost optical spectrometers design. The Biomedical Engineering project was EMG and Muscle Contraction. The Computer Science project had the students build a mBot robot by using Scratch programming language. The Electrical Engineering project involved an LED Dexterity Challenge and RGB LED with Potentiometers. The Manufacturing project had the students manufacture a miniature Bowling Pin. A survey was conducted to collect data right after the students completed each workshop to evaluate the content of the workshop. About 600 girl scouts members participated in the STEM program and took the survey in the past ten years. The survey showed 100% students enjoyed Biomedical Engineering project, 98% students enjoyed Electrical Engineering workshop activity, 100% of the students enjoyed Manufacturing Engineering, 97% students enjoyed Computer Science. Students reflected that they would like to participate more STEM related activities in the future.

The program represents the university’s ongoing efforts to interest young women in STEM and is part of the Girl Scouts' “fun with purpose” K-12 curriculum. That initiative introduces scouts of every age to STEM to inspire them to embrace and celebrate scientific discovery. It could also contribute toward the likelihood of these girl scouts pursuing STEM pathways and possibly entering engineering fields.

Introduction

Nowadays, more and more scientists, engineers and innovators are needed to contribute and succeed in the global competitive economic environment. As a result, this requires quality science, technology, engineering and mathematics (STEM) education. However, insufficient numbers of American students pursue education and training in the STEM fields. After noticing this challenge, STEM has become a great effort by many to increase STEM-related activities, which have the potential to promote collaborative learning and inquiry as well as to contribute to

the development of the 21st century skills [1]. The US government initiated the “Educate to Innovate” program to increase student participation in all STEM-related activities. The long-term objective of these activities is to encourage more young women to choose an education in STEM in the future [2].

Attracting more female students into the STEM fields is a challenge. Statistics show that there is a big gender gap in the STEM fields in workplaces. It has been found that the women make up 46% of the workforce, but women have only 24% of jobs in STEM fields [3]. More women in STEM careers have at least two primary benefits. First, STEM careers typically have higher salary, benefits, and career stability in the workforce [14]. Secondly, a more diverse workforce in STEM jobs will lead to more diversity in solutions and designs [15]. Possibly, these designs that are more influenced by women will be more holistic, sustainable, safe, and fit better with people and society.

Many institutions and organizations have realized this challenge and provided various activities to promote female students into the STEM fields [2]. In addition, different strategies were developed to recruit and retain students in the STEM education [4-5]. To make efforts in this direction, our university collaborates with a Girl Scouts organization and has run a Girl Scouts STEM Day program targeted to help 4th or 5th grade students explore STEM fields. It started with 30 students in 2014 and increased to the highest number of 96 before COVID. We skipped the event in 2020 due to COVID. In the past ten years, over 600 girl scouts participated in the skills-based workshops and hands-on projects.

The one-day program featured five different STEM workshops: Biomedical Engineering, Electrical Engineering, Manufacturing, Computer Science, and Science. The workshop offerings vary each year based on the faculty leading the modules. Over the ten years there were more than 20 faculty and staff that helped run the events. Each time we have more than 25 student volunteers to help with the events. During the event day, the Girl Scouts participated in each workshop for 45 minutes before rotating to the next one. To keep the program fresh for returning Girl Scouts, two different activities were alternated each year for each workshop. These workshops were led by faculty members from various engineering disciplines, and supported by 3-5 college student volunteers. The group size for each workshop ranged from 15 to 18 Girl Scouts. The number of participants varied each year. And the number and makeup of faculty members who participated varied as well. Many of the student volunteers were members of the SWE, while others came from the general student body. The student volunteers played a vital role in the Girl Scouts' experience, helping to explain the activities and serving as role models. Throughout the workshops, the girl scout participants frequently asked questions and engaged with the student volunteers, both during and after the activities.

This paper describes our experience of conducting the one day program to expose young girls to the STEM fields. This paper presents our analysis of the Biological Engineering, Biomedical Engineering, Computer Science, Electrical Engineering, and Manufacturing workshops, including preparation, implementation, survey data, observations, and findings.

Workshop Implementation

In higher education, laboratory exercises are known to play an important role in engineering education [9-11]. They provide the opportunity for students to work on modern machines, and use tools used in industry [12]. The education of students in our university is enhanced by the many opportunities to learn by doing. As a university, we have modern machines and tools that a girl scout can be exposed to, which provide high value opportunities. Therefore, in our workshops, we focused on hands on activity using modern machines and tools.

Biological Engineering Workshop

The Biological Engineering workshop named "Sensing Technologies of the Biological Engineer" included participants in an in-depth analysis of the making of optical biological sensors and their use as both stand-alone technologies and integrated elements of larger machinery. Participants designed low-cost optical spectrometers and participated in both qualitative and quantitative analysis of control samples.

To orient students in the fundamentals of engineering design, a brief introductory lecture was delivered that outlined the basic science behind the sensing technology, including electromagnetic radiation, incident light, descriptions of the parts of a spectrometer and their functions (slit, prism/ diffraction grating, and detector). The use of spectrometers in bioengineering applications (especially in those of remote or low- resource settings) was also introduced.

Girl scout participants were then guided through the design and construction of their own model of low-resource spectrometers from commonly available materials (cardboard, construction paper, diffraction gratings (cardboard diffraction glasses), plastic housings). Participants were able to obtain qualitative data on spectra of different test samples, as well as compare these to a quantitative model. After the activity, the students compared their qualitative analysis and discussed sensor accuracy and possible design reiterations. Figure 1 shows the image of spectra from low-resource spectrometer.

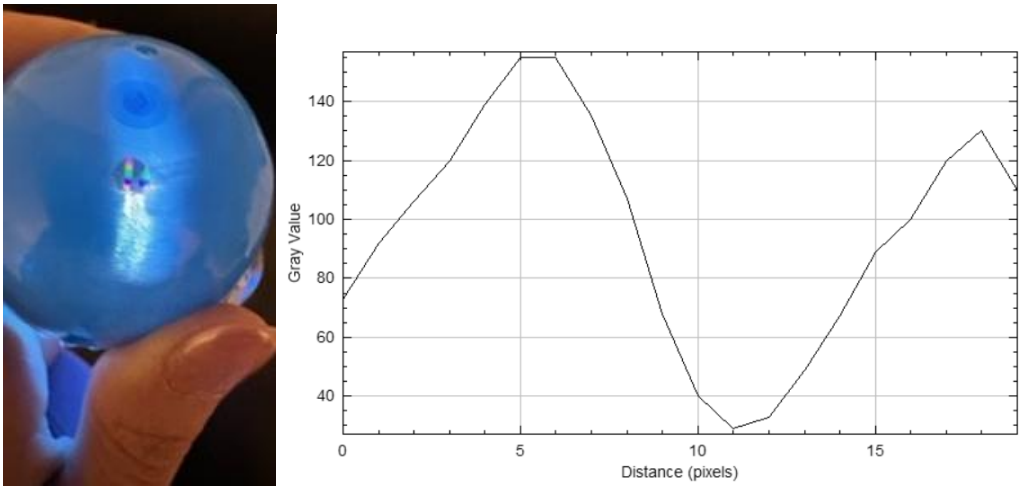

Figure 1. Image of spectra from low-resource spectrometer

Biomedical Engineering Workshop

The Biomedical Engineering (BME) workshop "EMG and Muscle Contraction" was designed to have the participants use hand dynamometers with other sensors (e.g., EKG sensors and disposable skin electrodes) to study the graphical representation of the electrical activity of a muscle (EMG) and how it is related to muscle contractions.

Since biomedical engineering (BME) is a relatively new and interdisciplinary field, a brief introduction of BME was given to the girl scouts at the beginning of the workshop. Some background information (e.g., neurons, biopotentials, EMG, etc.) was also illustrated along with the experimental setups. Girl scouts then used the Logger Pro program (from Vernier SCIENCE EDUCATION) that was preloaded to their laptops. They recorded the electrical activity of the lower arm muscle associated with hand grip force (Figure 2).

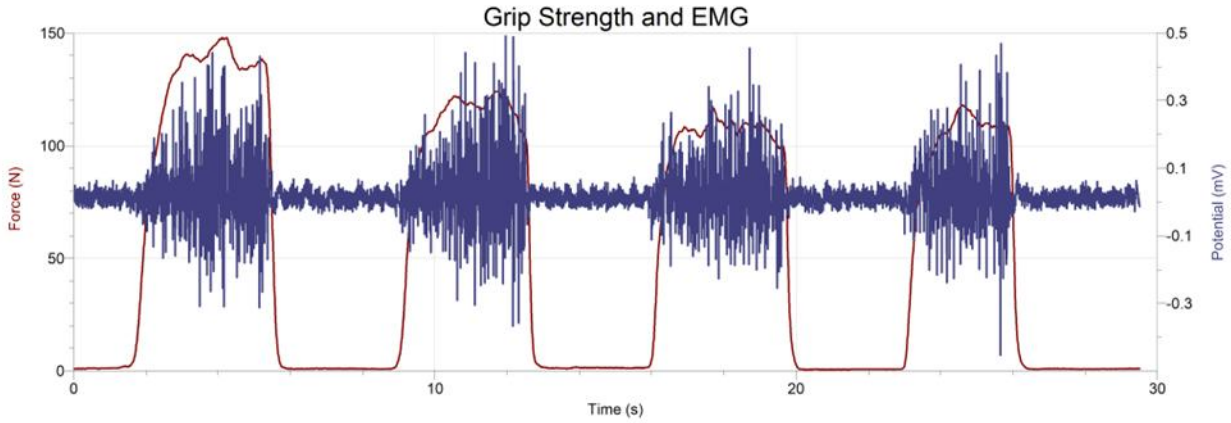

Figure 2. Hand grip strength and EMG signals.

After the activity, girl scout participants compared the strength of the force they recorded and discussed the applications of EMG in biomedical engineering (e.g., neuromuscular disease diagnosis, rehabilitation evaluation, and control strategy for assistive devices.

Computer Science Workshop

The Computer Science workshop "Obstacle Avoidance Robot" aimed at exposing participants to relevant and interesting topics in the robotics field such as autonomous cars. The project consisted of programming the robot illustrated in Figure 3, called mBot, to avoid obstacles while communicating its movements effectively to the environment. mBot is an educational robot for students to learn hands-on control in the fields of graphical programming, electronics, and robotics. Students learn how to and then program the mBot using block-based programming [16]. Before starting with the hands-on activities, an introductory lecture was conducted. To engage the students

and explain how obstacle avoidance is performed an analogy with bats was introduced. Bats emit sound waves to detect obstacles and maneuver around them to navigate through darkness. Similarly, these mBot devices utilize sensors to 'see' their environment and adeptly navigate obstacles.

Figure 3: mBot platform used in the workshop activities.

The activity was divided into four different tasks to make sure students could independently progress on the different tasks at their own pace. Hands out were provided with clear instructions on the steps and on how to use block coding to perform the required tasks.

- **Task 1 Start up!:** The first activity consisted in connecting the mBot to the laptop via USB and connect it the desktop
- **Task 2 Obstacle Avoidance:** Students started writing the code to enable mBot to move forward, to stop for 2 seconds when an obstacle was at distance less than 20 centimeters and move backwards for 3 seconds. The classroom walls were used as obstacles.
- **Task 3 Warning lights on mBots:** After the scout participants successfully tested the code for obstacle avoidance, they were asked to use the LED on the mBots to communicate their movements. They programmed the mBot to flash a green light when moving forward, a red light when stopping and a blue light when moving backwards.
- **Task 4 Honking the horn of mBots:** Lastly, students programmed the robot to honk the horn at different frequency when the mBot stopped and when moved backwards.

Some groups completed all the tasks before the end of the module. As a result, they began experimenting with the mBots, making them interact with one another. This final activity was where they seemed to have the most fun.

Electrical Engineering Workshop

The first Electrical Engineering Workshop activity was called “Light Emitting Diode (LED) Dexterity Challenge”. The activity had the girl scout participants build and test a circuit that could test one’s ability of hand-to-eye steadiness and accuracy. The challenger that transversed the greatest length or wire without electrical contact was the winner. The girl scouts built a circuit with a LED, a resistor, and the battery. They added a piece of bus wire to create the game. Shape the bus wire into any shape they wanted, like a Valentine heart. Figure 4 shows the final circuit.

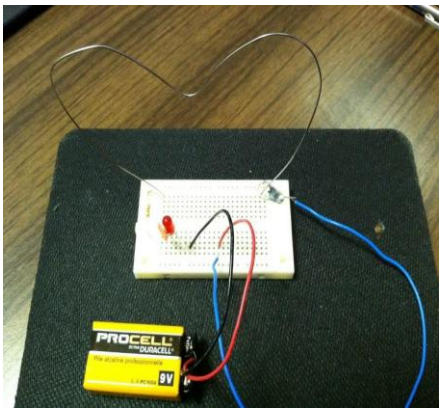

Figure 4 LED Dexterity Challenge circuit.

Another Electrical Engineering Workshop activity was called “RGB LED with Potentiometers”. The activity had the scout participants build and test a circuit with a RGB LED, one 220 Ω resistor, and a potentiometer. Then they connected a power supply to power this circuit. The scout would then rotate the screw of the pot to see if the LED brightness changed. Depending on what pin the pot was attached to (R, G or B), the LED would have that color. As the wiper ranged from 0 V to 5 V, the LED should go from dark to bright.

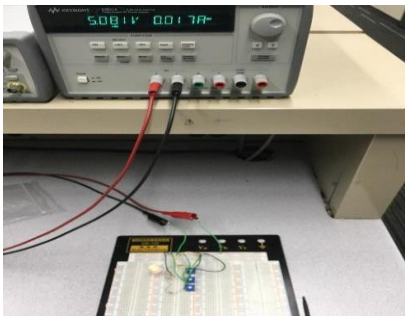
Figure 5 shows the circuit connection.

Manufacturing Engineering Workshop

In the manufacturing workshop, participants have the opportunity to operate a lathe to create different parts, such as a bowling pin or a chess piece pawn. At the start of the workshop, participants were given a brief lecture about machine shop safety. Safety glasses were provided to each of them. The 3D models for the bowling pin or pawn were created in advance, and the CNC machining codes were pre-programmed. Participants operated the lathe by controlling the handle to shape the parts.

Typically, six college student volunteers were present to monitor the six lathes. They stood beside each machine to guide the girl scout participants through the operation. They explained how the lathes worked and demonstrated the process by making a sample piece. Participants then followed the demonstration to create their own pieces. Afterward, they use files to smooth the cutting

surfaces and finish their work. Figure 6 shows the CNC lathe and the 3D model of the bowling pin.

Figure 6 – CNC Lathe and 3D model of bowling pin

Survey Questions

A survey was conducted to collect data right after students completed the workshop to evaluate the content of the workshop. 600 female students participated in the Girl Scouts STEM Day workshops over the past ten years and almost all of them took the surveys. Following are the questions we asked students in the survey:

Table 1: Survey Questions

Did you learn something new during this activity? (a) I learned a lot (b) I learned some (c) I did not learn anything (d) I was confused	Did you enjoy the activity? (a) I really liked it (b) I liked it (c) It was OK (d) I did not like it (e) It was boring

Survey Results

The survey results for the Electrical, Biomedical, Manufacturing, and Computer Science workshops are shown in Figures 7 and 8. The event began with a Science workshop focused on chemistry. However, due to changes in faculty availability, the workshop was later switched to a Biological Engineering workshop, which was biology-oriented. As a result, the data from the Science or Biological Engineering workshop was not included in the results.

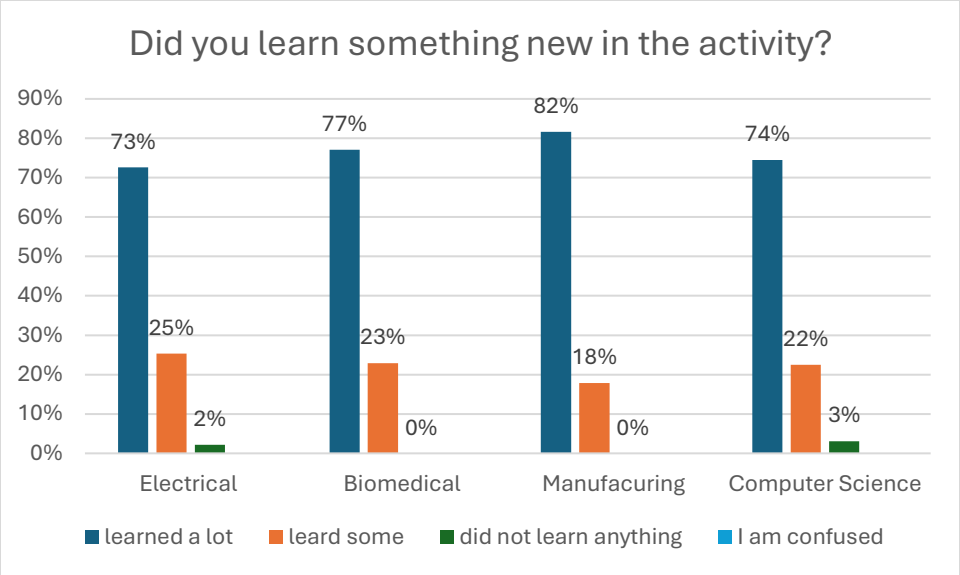

Figure 7 Survey results for Question 1

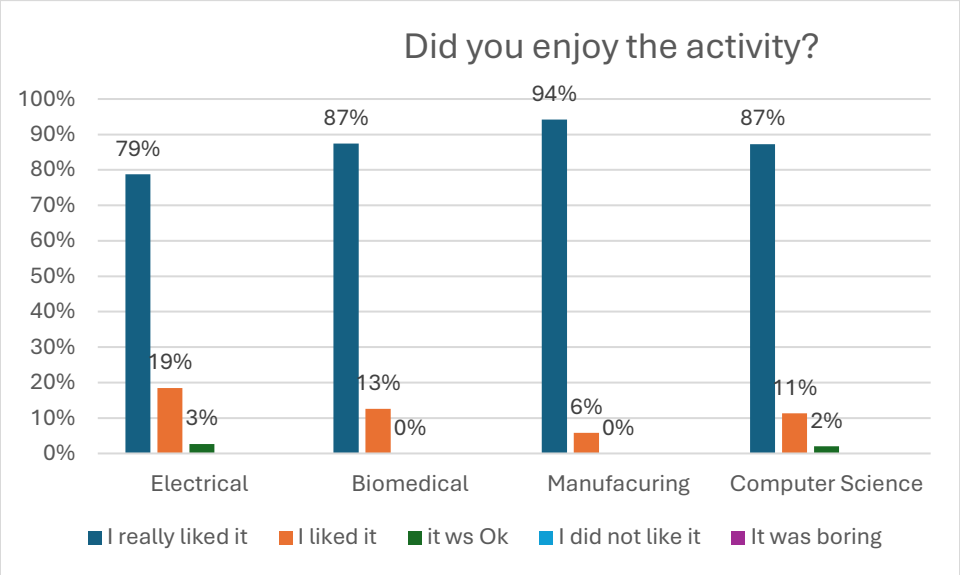

Figure 8 Survey results for Question 2

The results indicated that most students had a positive experience with the program. The majority expressed satisfaction with the overall event. All participants reported liking or strongly liking the Manufacturing and Biomedical workshops. Approximately 97% to 98% of the Girl Scouts indicated that they liked or really liked the Electrical and Computer Science workshops. In terms of learning, about 73% to 82% of the Girl Scouts stated that they learned a lot in these workshops, while 18% to 25% expressed that they learned something.

Discussion and Conclusion

The overall outcome of the Girl Scout event was positive, with the majority of participants either learning something or a lot and thoroughly enjoying the experience. The workshops varied over the years, with Electrical, Biomedical, Manufacturing, and computer science being sustained, while the Science workshop recently shifted its focus from Chemistry to Biological Engineering. Several key aspects of the event are worth noting:

- University Campus Setting: Hosting the event at a university campus provided the girl scout participants with a valuable opportunity to explore the college environment. They visited modern labs, got a feel for what a college campus is like, and interacted with college students.
- Student Volunteers: Student volunteers were vital to the success of the event. Since the girl scout participants were young, they needed considerable assistance when using lab equipment, and student volunteers were essential in providing this guidance. Additionally, the volunteers served as role models, inspiring the scout participants in their academic and career aspirations. However, recruiting a sufficient number of volunteers could sometimes be challenging. Each year, we recruited around 25~30 student university student volunteers for this event. The university also required specific training and paperwork for volunteers working with minors, which added an extra layer of complexity to the recruitment process.
- Faculty Availability: Another challenge was ensuring faculty availability, as the event took place on a Saturday. Faculty members must sacrifice personal time to participate, and they also needed to prepare the workshops in advance, adding to their workload.
- Funding for the workshop: Fortunately, the School of Engineering has been very supportive of STEM outreach. This strong institutional backing ensured that we could offer high-quality workshops and expand our outreach efforts. However, continued support and additional funding opportunities would be essential for the future growth and sustainability of the program.

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