Girl Scouts STEM Day Program

Dr. Jiahui Song, Wentworth Institute of Technology

Jiahui Song received her B.S. in Automation and M.S. in Pattern Recognition & Intelligent Systems from Southeast University. She received her Ph.D. in Electrical and Computer Engineering from Old Dominion University. She is currently an Associate Professor in the Department of Electrical Engineering and Technology at Wentworth Institute of Technology.

Dr. Douglas Eric Dow, Wentworth Institute of Technology

Professor at Wentworth Institute of Technology in the Department of Electrical and Computer Engineering (started 2008). Education B.A. in Liberal Arts Engineering from Wheaton College (Wheaton, IL); B.S. in Electrical Engineering from Texas A&M University (College Station, TX); M.S. in Computer Science from University of Colorado (Colorado Springs, CO); M.S. and Ph.D. in Biomedical Engineering from University of Michigan (Ann Arbor, MI). Worked in industry for about 9 years at Ampex Corporation (video systems manufacturing) in Colorado Springs CO, Panasonic (central research lab) in Osaka, Japan, and National University of Singapore (center for image enhanced medicine) in Singapore. Post Doc or Sabbatical research was done at Tohoku University (biology information systems) in Sendai, Japan, Mayo Clinic (respiration research lab) in Rochester MN, and Kansai University (knowledge information systems) in Osaka, Japan. Core focus involves embedded electronic systems for applications in medical rehabilitation, health monitoring, physical therapy and assistive technologies. This involves development of hardware and software systems with sensors, embedded control and mechanical actuators. Applications include respiration monitoring, sleep apnea, rehabilitation of impaired muscle for recovery of motor function, health monitoring for elderly to extend independent living, and diabetes management. These systems utilize internet of things (IoT) for remote communication between patient, medical staff, care-givers and instrumentation.

Dr. Gloria Guohua Ma, Wentworth Institute of Technology

Gloria Ma is a Professor in the Department of Mechanical Engineering and Technology. She has been teaching robotics with Lego Mindstorm to ME freshmen for several years. She is actively involved in community services of offering robotics workshops to middle- and high-school girls. Her research interests are dynamics and system modeling, geometry modeling, project based engineering design, and robotics in manufacturing.

James R McCusker PhD, Wentworth Institute of Technology

James R. McCusker is an Associate Professor at Wentworth Institute of Technology in the Department of Electrical Engineering. Since joining Wentworth in 2010, he has been heavily involved with an array of interdisciplinary design courses that range from introductory to capstone courses.

Girl Scouts STEM Day Program

Abstract

Careers in engineering help a person to both contribute toward solving problems in society and environment, and live independently with available work and sufficient salary. Nevertheless, a disproportionate number of females have not entered careers in engineering or related STEM fields. 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 Wentworth Institute of Technology 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 organization is led by the Society of Women Engineers (SWE). The core part of the day has small groups of Girl Scouts rotate between workshops. These workshops were conducted by faculty from different departments. In each workshop, one faculty and several college student volunteers, led by the SWE student chapter, introduced and guided the activity. Members of Girl Scouts participated in STEM-related hands-on workshops. The event was first started at our university in 2014 with 30 students, and has grown to over 75 students in 2019. In the past six years, over 340 girl scouts 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 broke into small groups and rotated through five different STEM workshops: Biomedical Engineering, Electrical Engineering, Manufacturing Engineering, Computer Science, and Science. There was about forty five minutes for each workshop. Descriptions and observations of the Biomedical Engineering, Electrical Engineering, and Manufacturing Engineering workshops are presented in this paper. The Biomedical Engineering project involved sensors for muscle force and electromyography with resulting graphs. The Electrical Engineering project involved an RGB LED with Potentiometers. The Manufacturing Engineering 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.

The program was motivated to expose young girls to STEM fields, boost interests and give them more hands-on experience. It could also contribute toward the likelihood of these girl scouts to pursue STEM pathways and possibly enter engineering fields.

Introduction/Background

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 the 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]. Since 2014 Wentworth Institute of Technology has organized a Girl Scouts STEM Day program targeted to help 4th or 5th grade students explore STEM fields. It started with 30 students, and the number of students increased to 75 in 2019. In the past six years, over 340 girl scouts participated in the skills-based workshops and hands-on projects.

There were five different STEM workshops in this one day program: Biomedical Engineering, Electrical Engineering, Manufacturing Engineering, Computer Science, and Science. The girl scouts explored a STEM workshop for forty five minutes and then rotated to a different workshop. These workshops were conducted by faculty from different departments. In each workshop, one faculty and several college student volunteers introduced and guided the activity. A group of 15-18 girl scouts would participate a workshop. Besides the faculty member, 3-5 college student volunteers helped. Many of the student volunteers were from the Society of Women Engineers (SWE) student chapter, and others were from the general student body. The student volunteers played a large role in the girl scouts experience with the activity. The student volunteers explained the activity and acted as role models. During and after the activity, the girl scouts usually asked many questions of the student volunteers.

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

Workshop Implementation

Laboratory exercises play an important role in engineering education [9-11]. They provide the opportunity for students to work on modern machines, tools used in industry [12]. Therefore, in our workshops, we focused on hands on activity using modern machines and tools.

Biomedical Engineering Workshop

This workshop explored muscle contractions, both the electromyogram (EMG) signal and the resulting force generated by the muscle contraction. The EMG is a voltage signal that can be measured by skin electrode patches near a muscle. This electrical activity originates as nerve pulses in the brain and spinal cord, passing through the motor neurons in the peripheral nervous system to the skeletal muscle. The measurable voltage signal is made by ions passing through the membranes of nerve and muscle cells during this process. The stronger the EMG signal, the stronger the resulting muscle contraction.

National Instruments (Austin, TX) data acquisition modules (myRio) were utilized for the computer interface, analog to digital conversion and instrument control. Vernier (Beaverton, OR) biomedical sensor modules were used for the EMG and hand grip force measurements. The Vernier EKG sensor module was used for EMG of the forearm muscles, and the Vernier Hand Dynamometer sensor module was used to measure the force of hand grip during muscle contractions. A custom made LabView (National Instruments) program developed prior to the exercise was used for instrument control, data acquisition and display of results. In the program, the EMG signal was offset corrected, normalized for amplitude, rectified and windowed average to make a smoothed plot for net muscle contraction intensity. The force signal from the dynamometer was offset corrected, normalized for amplitude and plotted. Both plots had the time axis matching from start to end of the recording session.

Following a brief lecture providing muscle physiology and background information, the flow of the exercise was guided by the student volunteers as follows.

Step 1: Connect wires to a prototype circuit board that was attached to the myRio data acquisition module, following a diagram. Connect an adaptor between the cables of each Vernier sensor module and the prototype circuit board.

Step 2: Place electrode skin pads on the student volunteer with two on the forearm muscles about 2-3 cm apart, and a third pad on the opposite-side wrist or ankle to function as a reference ground. Attach the input cables from the Vernier EKG module to these pads.

Step 3: Have the student volunteer grip the Vernier Hand Dynamometer, on the same arm as the two skin electrode pads on the forearm muscle.

Step 4: Run the LabView program. Have the student volunteer make several cycles of relax, hand grip squeeze, and relax. Stop the recording to view the plots of the recorded EMG and Force signals.

Step 5: Look at the plots from the LabView program on the computer screen. Discuss the correlation between the intensity of the EMG signal and the force of the hand grip during the squeeze and relax cycles undertaken by the student volunteer.

Electrical Engineering Workshop

The Electrical Engineering workshop activity was called RGB LED with Potentiometers. The activity had the girls build and test a circuit. This took seven steps to accomplish. The flow of the activity was guided by the following steps that were given by the student volunteers.

Step 1: Insert pins of RGB LED into prototype board, so that each pin is in a different row (5-hole row). Remember which pin is the longest one (GND).

Step 2: Attach wire from LED longest leg (pick any hole in same set of 5 holes in that row) to a blue or black strip (long column, length of prototype board). This blue or black strip will be the GND of the circuit.

Step 3: Attach one 220 Ω resistor to each or the other legs of LED. Have other end of resistors go to a new 5-hole row. Spread out the resistors.

Step 4: Insert a potentiometer (pot) at end of one of the resistors. Have the middle pin (the "wiper") of the pot be in the same 5-hole row as the resistor. Attach one of the pot's outer pins to GND, the long blue strip. Attach the other pot's outer pins to power, a long red strip.

Step 5: Use Power Supply to power this circuit

- Connect Alligator black lead to GND of prototype board (blue strip)
- Connect Alligator red lead to 5V power of prototype board (red strip)

Step 6: Rotate the screw of the pot. See if the LED brightness changes. Depending on what pin the pot is attached to (R, G or B), the LED will have that color. As the wiper ranges from 0 V to 5 V, the LED should go from dark to bright.

Step 7: Attach the other pots to the other 2 LED pins (so each R, G and B pins have their own pot). Test adjusting the color using the 3 pots.

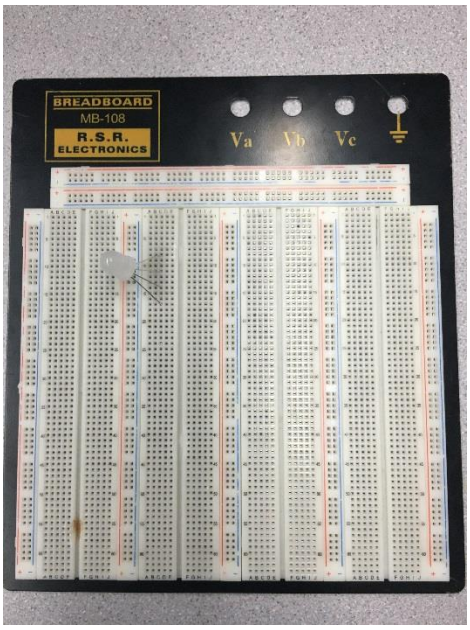

Figure 1 RGB LED with Potentiometers Step 1

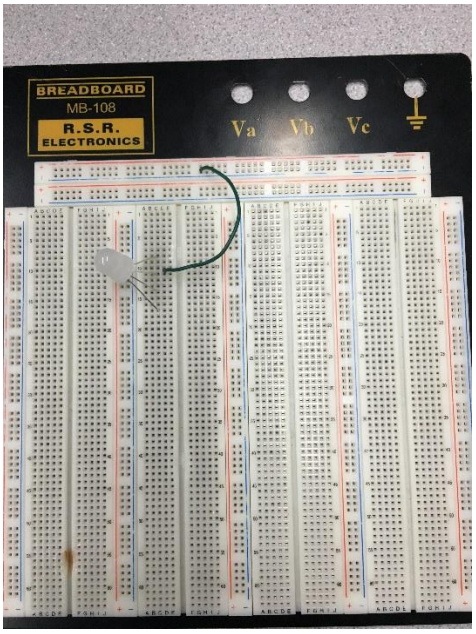

Figure 2 RGB LED with Potentiometers Step 2

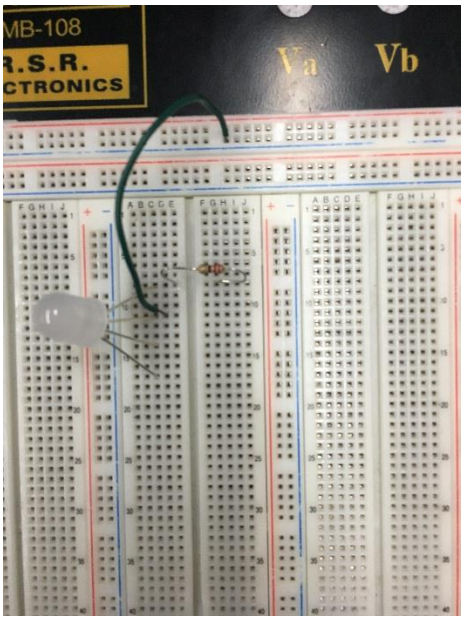

Figure 3 RGB LED with Potentiometers Step 3

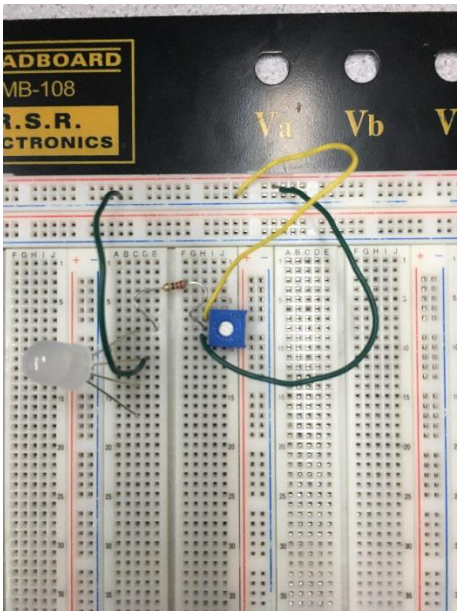

Figure 4 RGB LED with Potentiometers Step 4

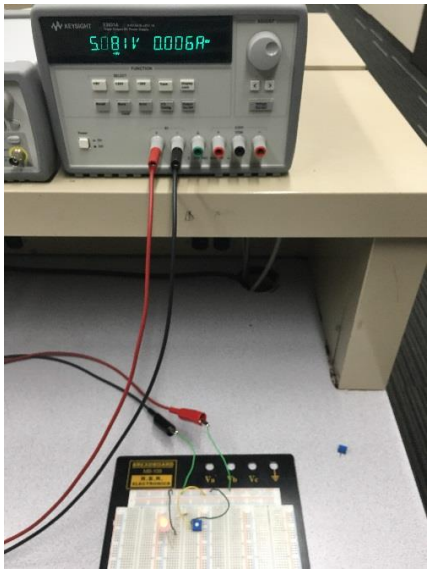

Figure 5 RGB LED with Potentiometers Step 5 and 6

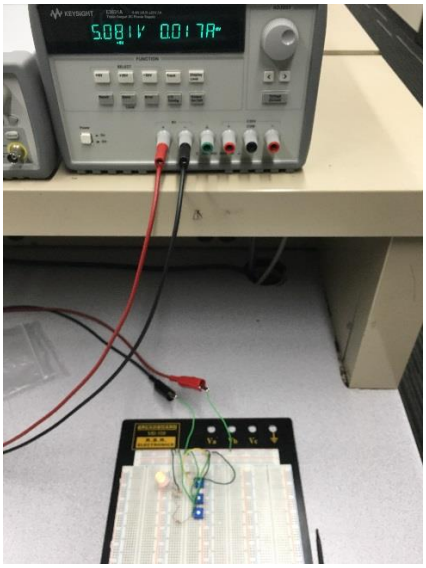

Figure 6 RGB LED with Potentiometers Step 7

Manufacturing Engineering Workshop

The Manufacturing Engineering workshop activity was called Making Bowling Pin. Manufacturing is the final step of making a product. In this workshop participants were exposed to computer numerically controlled (CNC) lathe and they assisted in the operation of the equipment to shape a small aluminum bowling pin. Figure 7 shows the SolidWorks Model of a bowling pin, and Figure 8 shows a typical CNC lathe in the manufacturing center. To make the exercise accessible to students having little or no prior manufacturing on CNC machine experience, G code of making the bowling pin was pre-programmed and installed to each lathe. Safety is one of the key elements for this workshop. Volunteers certified to operate lathe machines were assigned to each lathe to help ensure safety. A safety presentation was delivered prior to use of the lathes. Some other safety considerations are:

1) No unattended students in the Manufacturing Center.
2) Students not permitted to touch inside the lathe, all set up must be done by a qualified volunteer.
3) Safety glasses worn at all times within the designated manufacturing area.
4) No jewelry, loose clothing, open toed shoes allowed in the Manufacturing Center, long hair must be tied back.
5) All safety guards in place prior to activation of the lathe.

Some students came unprepared, and some forgot tie their hair back safely. In these cases, pipe cleaner was used to tie back hair. This method was enthusiastically received by the students. After making the bowling pin, the participants smoothed the cut surfaces (the bottom of the bowling pin) by a file, and they could bring it home.

Figure 7 Bowling Pin modelled in SolidWorks.

Figure 8 CNC Lathe in manufacturing center

Survey Questions

A survey was conducted to collect data right after students completed the workshop to evaluate the content of the workshop. 244 female students participated in the Girl Scouts STEM Day Biomedical, Electrical and Manufacturing Engineering workshops in the past four years and all of them took the surveys. Following are the questions we asked students in the survey:

Table 1: Survey Questions

Biomedical Workshop	**Electrical Workshop**	**Manufacturing Workshop**
1. 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 2. 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	1. 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 2. 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	1. 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 2. 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 are shown in Figure 9-14.

Biomedical Engineering Workshop

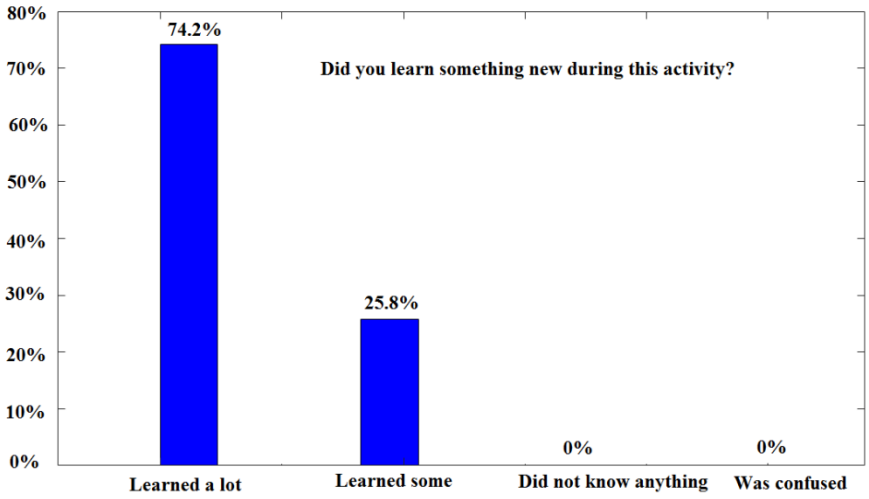

Figure 9: Survey results for "Did you learn something new during this activity?"

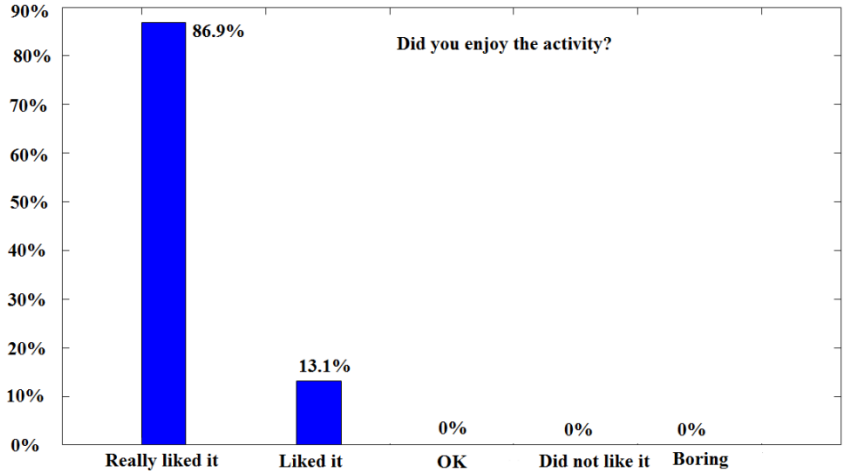

Figure 10: Survey results for "Did you enjoy the activity?"

Electrical Engineering Workshop

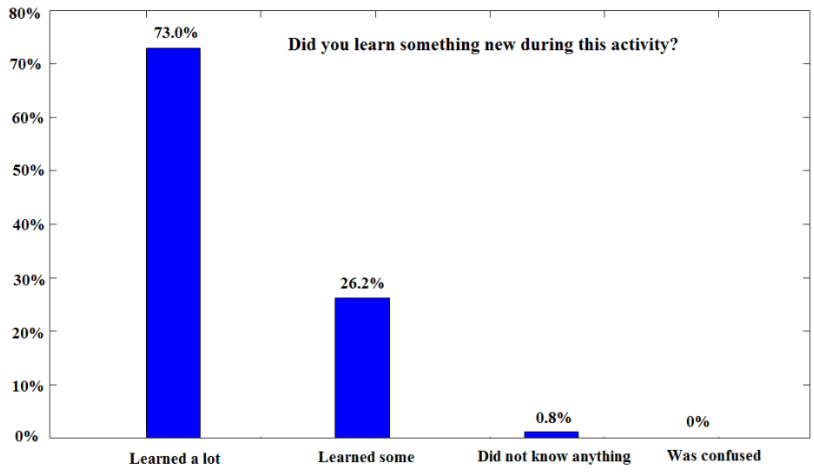

Figure 11: Survey results for "Did you learn something new during this activity?"

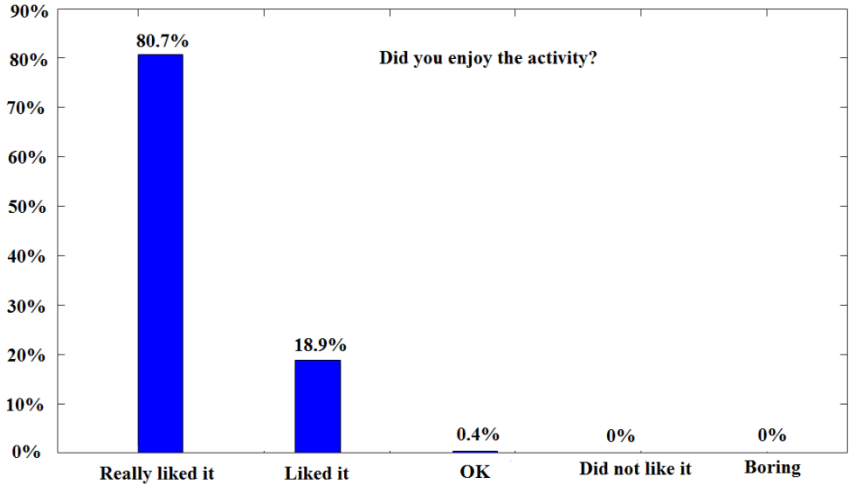

Figure 12: Survey results for "Did you enjoy the activity?"

Manufacturing Engineering Workshop

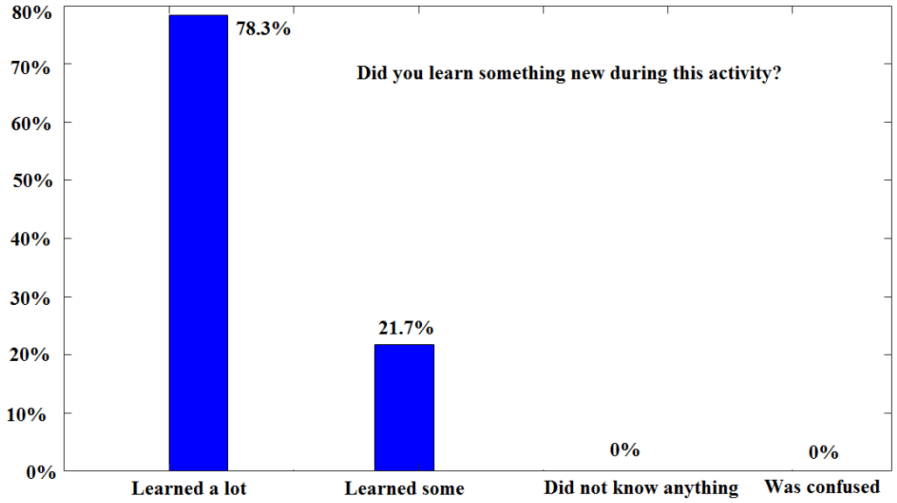

Figure 13: Survey results for "Did you learn something new during this activity?"

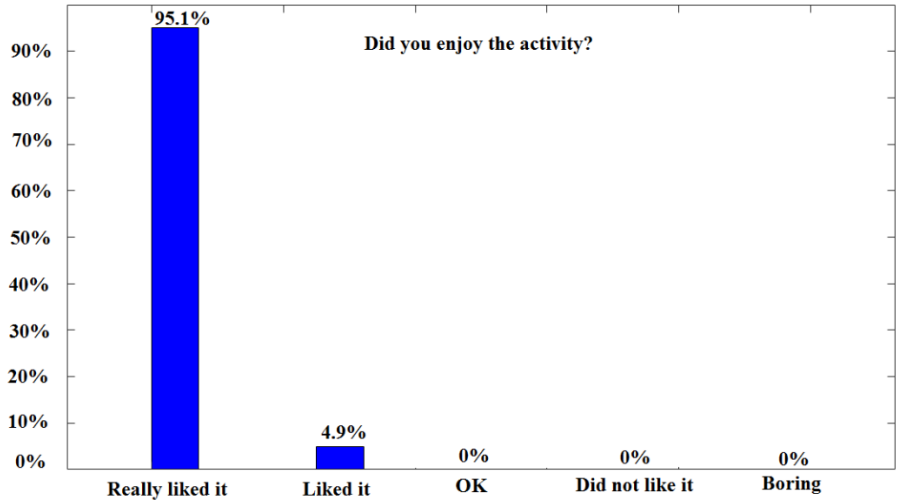

Figure 14: Survey results for "Did you enjoy the activity?"

The survey results indicate that many girl scouts enjoyed Biomedical, Electrical and Manufacturing Engineering workshops. 100% of the scouts learned some/a lot of Biomedical Engineering and Manufacturing Engineering, while 99.2% of the scouts learned some/a lot of Electrical Engineering. Scouts also reflected that they enjoyed the experience very much. 86.9% of the scouts really liked Biomedical Engineering workshop, 80.7% of the scouts really liked Electrical Engineering workshop, and 95.1% of the scouts really liked Manufacturing Engineering workshop. Students also found the workshops increased their interest in STEM courses.

Conclusions

Girl Scouts STEM Day program was motivated to expose young girls to STEM fields, boost interests and give them more hands-on experience. It could also fulfill our long-term objective of recruiting more female students into the STEM-related educational pathways and careers [13]. Biomedical, Electrical and Manufacturing workshops were presented in this paper. The survey results encouraged us that the workshops were interesting to the students and proper topics were selected. It also indicated that students enjoyed hands-on activities.

The experience gained from Girl Scouts STEM Day program will help organize similar workshops in the future. We believe these experiences would also benefit other educators and researchers with the common goal of increasing the number of female professionals in the STEM fields.

After completing Girl Scouts STEM Day grogram, students reflected that the workshops were interesting and they enjoyed STEM fields. On their evaluations, some wrote: “It is the best!” “It is fun”, “This program is cool!”. We had many girls came back from last year. We also had a troop from a place that 1.5 hours drive distance. Many of the parents asked our volunteers: "Are there any other events that you organize?" Our future direction would be to track the number of students who enroll in STEM fields for college after they finish Girl Scouts STEM activities.

References:

[1] Sahin, A., Ayar, M. C., and Adiguzel, T., "STEM Related After-School Program Activities and Associated Outcomes on Student Learning", *Educational Sciences: Theory and Practice*, 14(1), 309-322, 2014.

[2] Ma, G., and Ma, L., "Retaining Female Students in a Robotics Program", *Proceedings of the 2017 American Society for Engineering Education conference and exposition*, 2017.

[3] Crowe, S., "Robotics playing a bigger role in STEM education”, *Robotics Business Review*, May 27, 2005. URL: https://www.roboticsbusinessreview.com/rbr/robotics_playing_bigger_role_in_stem_education, accessed March 13, 2018.

[4] Zywno, M. S., Gilbride, K. A., and Gudz, N., "Innovative outreach programs to attract and retain women in undergraduate engineering programs", *Global Journal of Engineering. Education*, 4(3), 293-302, 2000.

[5] Doerschuk, P., Liu, J., and Mann, J., "INSPIRED broadening participation in computing: Most successful strategies and lessons learned", *In Frontiers in Education Conference (FIE)*, IEEE (pp. T2H-1), 2010.

[6] DeBartolo, E., and Bailey, M., "A continuous series of outreach programs to recruit young women to engineering. Age", *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition*, 2005

[7] Robnett, R., "The Role of Peer Support for Girls and Women in STEM: Implications for Identity and Anticipated Retention", *International Journal of Gender, Science and Technology*, 5(3), 232-253, 2013.

[8] Akl, R. G., Keathly, D., and Garlick, R., "Strategies for Retention and Recruitment of Women and Minorities in Computer Science and Engineering", *Innovations 2007: World Innovations in Engineering Education and Research*, 2007.

[9] Feisel, L.D. and Rosa, A.J., "The role of the laboratory in undergraduate engineering education", *Journal of engineering education*, pp. 121-130, January 2005.

[10] Thomas, J.W., "A review of research on project-based learning", *California: The Autodesk Foundation*. URL: http://www.bie.org/images/uploads/general/9d06758fd346969cb63653d00dca55c0.pdf, March, 2000. Accessed March 13, 2018.

[11] Waks, S. and N. Sabag, N., "Technology Project Learning Versus Lab Experimentation", *Journal of Science Education and Technology*, Volume 13, issue 3, pp. 333-342, September 2004.

[12] Song, J. and Ma, G., "Different Lab Formats in Introduction to Engineering Course", *Proceedings of the 2017 American Society for Engineering Education conference and exposition*, 2017.

[13] Song, J., & Ma, G. G., "RAMP: Summer Bridge Program for Female High School Students", *Proceedings of the 2018 American Society for Engineering Education conference and exposition*, 2018.

[14] Terrell, N., STEM occupations: High-tech jobs for a high-tech economy", *Occupational Outlook Quarterly*, Spring 2007.

[15] Gray, M. and Thomas, K., Strategies for Increasing Diversity in Engineering Majors and Careers, 2017.