

STEM Program for Female Students

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STEM Programs for Female Students

Abstract

Despite engineering careers helping to solve problems in society and the environment, and enabling financial independence, a disproportionately low number of women enter engineering careers. 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. Wentworth Institute of Technology has collaborated with local organizations and schools and initiated activities to provide exposure to role models and STEM activities to young women.

One example is a STEM day for Girl Scouts that has been organized at our university for six years. The one day program is 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 through five different STEM workshops. The event was first started in 2014 with 30 students, and has grown to 90 students in 2018. Since 2016 our university has developed a mini program "RAMP for High School Girls" to expose local junior and senior high school girls to STEM fields. The six-week summer program is organized as modules. Each week the female students explore a different STEM discipline. In the past 4 years, about 30 female students participated in the mini program each year. Last year our university started a new STEM program for freshman and sophomore students from a girls' high school. The event is organized by the student chapter of SWE. The one day program includes three STEM disciplines and the students rotated between the different workshops. 14 female high school students participated in this new STEM program last year.

A survey was conducted to collect data after each program to evaluate the content of the program. Over 87% of the participants really enjoyed Girl Scouts STEM day and 56% of the high school students knew some/a lot about STEM fields after RAMP program. Students also reflected that they would like to participate more STEM related activities in the future. Many high school students found the workshops to be extremely helpful in helping them to further identify their college interests and majors.

Introduction

Nowadays, more scientists, engineers and innovators are needed to solve complex problems in society and the environment. An increase in women entering STEM field would not only increase the total number of STEM workers but would also increase gender diversity of the STEM workforce. The ideas and focus arising from the more diverse STEM workforce may enhance innovation and generate more sustainable processes that improve protection of the environment. Recruiting more women into STEM pathways requires quality STEM education. However, few American students pursue education and training in the STEM fields. After noticing this challenge, the whole STEM society has made great efforts 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 also realized the shortage of STEM workforces. It initiated the “Educate to Innovate” program to increase student participation in all STEM-related activities. The ultimate objective of these activities is to encourage more students to choose an education in the STEM fields and pursue a STEM-related career in the future ^[2].

Attracting more female students into the STEM fields is a challenge. Even when women enter STEM fields, they are more likely to leave because of workplace issues ^[3]. Statistical data show that there is a big gender gap in the STEM fields in workplaces. It has been found that women make almost 50% of the workforce but hold only 28% of jobs in STEM fields ^[3]. 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]. Creating quality, attractive STEM programs ^[6] and using peer influence to motivate high school girls to enter the STEM fields ^[7-8] appears to be effective ways to retain female students in STEM.

Wentworth Institute of Technology has collaborated with local schools and organizations to promote STEM education. Since 2014 our university 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 was increased to a high of 90 in 2018. In the past six years, over 340 girl scouts participated in the skills-based workshops and hands-on projects. Since 2016 our university has developed a program "RAMP for High School Girls" to expose local junior and senior public high school girls to STEM fields. In the past 4 years, about 30 female students participated in the program each year. Last year our university started a new STEM program for freshman and sophomore female high school students from a private girls' high school. 14 students participated in this new STEM program. All event organizations were led by the Society of Women Engineers (SWE).

This paper describes our experience of conducting different programs with local organizations and schools to expose young girls to the STEM fields, including preparation, implementation, survey data, observations, and findings.

Program Implementation

Laboratory exercises play an important role in engineering education ^[9-11]. They provide the opportunity for students to work on modern machines and the tools used in industry ^[12]. Therefore, in all of our programs, we focused on hands on activity using modern machines and tools. Table 1 shows the participants, volunteers and time duration for each program.

Programs	Participants	Volunteers	Time
Girl Scouts STEM Day	4th or 5th grade students	SWE	1 day
RAMP Program	Junior and senior high school students	SWE	6 weeks
STEM Program for Female High School Students	Freshman and sophomore high school students	SWE	1 day

Girl Scouts STEM Day

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. 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. A group of 15-18 girl scouts would participate a workshop. In each workshop, besides the faculty member, 3-5 college student volunteers introduced and guided the activity. Many of the student volunteers were from 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 ^[13].

Biomedical Engineering workshop explored muscle contractions, both the electromyogram (EMG) signal and the resulting force generated by the muscle contraction. This workshop activity recorded both the EMG and Force signals of muscles. These signals were used to control actuators (motor or light). Such a system could be used to help a disabled person control devices in their vicinity.

Electrical Engineering workshop was called RGB LED with Potentiometers. The activity had the attendee build and test a circuit. The flow of the activity was guided by the steps that were given by the student volunteers. Figure 1 shows the final circuit of RGB LED with Potentiometers.

Manufacturing Engineering workshop introduced the attendee to machining principles and shop safety. The lab finished with a hands-on demonstration of a Computer Numerically Controlled (CNC) lathe. Each attendee got to keep the part that they make while assisting the lathe operators during the demonstrations. Figure 2 shows CNC Lathe in manufacturing center.

Computer Science workshop worked on a Line Follower Robot, an automated guided vehicle, which follow a visual line embedded on the floor. Attendee learned how to make the robot (mBot) move along the black line on the floor.

Science workshop discussed the properties of acids and bases and use cabbage leaves to create a pH indicator. Using the cabbage PH indicator, the attendee tested common household foods and products.

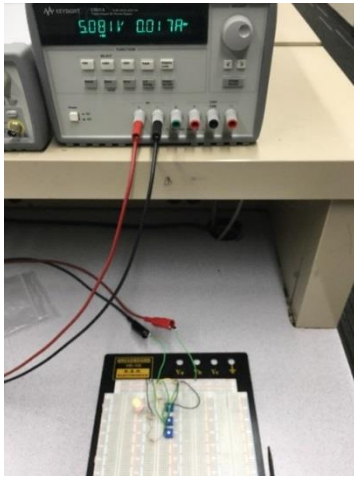


Figure 1. RGB LED with potentiometers



Figure 2. CNC Lathe in manufacturing center

RAMP Program

Since 2016, our university has collaborated with local public high schools and created a mini program "RAMP for High School Girls" to expose high school junior and senior female students to STEM fields. The main goal of the mini program is to expose female students to various STEM disciplines. Therefore, the mini program is organized as modules. There were 6 different modules: Biomedical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Computer Science, and Industrial Design. The high school girls explored all 6 STEM/Design modules over six weeks. Each week, they explored a different STEM workshop for two hours per day and twice a week. These workshops were conducted by faculty from different departments. In each workshop, besides overviewing the field and major, faculty's own experience in the field and teaching, career options within major, hands-on activities were also introduced to the students.

Electrical Engineering workshop exposed students to Arduino microcontroller to encourage student engagement by a fun project called Autonomous Vehicle ^[12]. The project included 2 sequential labs: Lab 1 Pulse Width Modulation, and Lab 2 Arduino Pulse Width Modulation. This workshop included both software and hardware. Students were exposed to coding (loops, conditionals, and debugging), wiring, oscilloscope, DMM, function generator, and DC power supply use. Figure 3 shows Hardware connection of autonomous vehicle.

Mechanical Engineering workshop introduced two experiments: Heat Engine and tensile test, which represent two different areas of Mechanical engineering: Thermo-fluid and Solid Mechanics. In the Heat Engine lab, different thermodynamic processes were discussed:

isothermal, isobaric, and isovolumetric. In Tensile test, the properties of materials were discussed, as well as the experimental way to obtain them and how to use them. Figure 4 shows the Tensile test with an Instron machine.

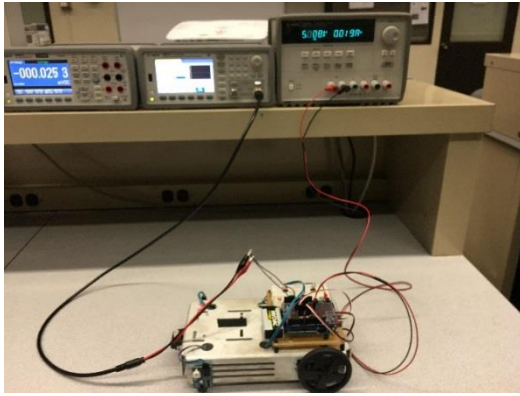


Figure 3. Hardware connection of autonomous vehicle



Figure 4. Tensile test with an Instron machine

STEM Program for Female High School Students

This program aimed to help high school female freshman and sophomore students explore STEM fields. Therefore, the program was organized as modules. There were 3 different modules: Biomedical Engineering, Electrical Engineering, and Mechanical Engineering. The high school girls explored a different STEM workshop for one hour each during the one-day program. These workshops were conducted by faculty from different departments. In each workshop, besides overviewing the field and major, and doing a hands-on STEM activity, the students were also introduced to the faculty's own experience in the field and teaching, career options within the major or field.

Biomedical Engineering workshop introduced electrocardiograph to students as a primary tool for evaluating electrical events within the heart. The electrodes were placed on the forearm and ankle. The students observed the change of heart rate in the ECG when they were in different positions and did different breathing patterns.

The Electrical Engineering workshop main activity was called Sensor Ranges Read by Arduino Software. The activity had the participants build and test a circuit and write or modify a C program, and then download it to Arduino.

The Mechanical Engineering workshop activity was called Making Bowling Pin. Manufacturing is the final step of making a product. In this workshop participants were exposed to a computer

numerically controlled (CNC) lathe and they assisted in the operation of the equipment to shape a small aluminum bowling pin. Figure 5 shows Bowling Pin modelled in SolidWorks.



Figure 5. Bowling Pin modelled in SolidWorks

Survey Questions and Results

Girl Scouts STEM Day

A survey was conducted to collect data right after students completed the workshop to evaluate the content of the workshop. 300 female students participated in the Girl Scouts STEM Day workshops in the past five years and all of them took the surveys. *Table* lists the questions we asked students after they completed each workshop.

Table 2. Survey Questions for Girl Scouts STEM Day

<p>1. Did you learn something new during this activity?</p> <p>(a) I learned a lot</p> <p>(b) I learned some</p> <p>(c) I did not learn anything</p> <p>(d) I was confused</p>	<p>2. Did you enjoy the activity?</p> <p>(a) I really liked it</p> <p>(b) I liked it</p> <p>(c) It was OK</p> <p>(d) I did not like it</p> <p>(e) It was boring</p>
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From survey results, many girl scouts enjoyed the workshops. 100% of the scouts learned some/a lot of Biomedical Engineering, Manufacturing Engineering and Science, 98.3% of the scouts learned some/a lot of Electrical Engineering, while 96.6% of the scouts learned some/a lot of Computer Science. Scouts also reflected that they enjoyed the experience very much. 88.0% of the scouts really liked Biomedical Engineering workshop, 87.7% of the scouts really liked Electrical Engineering workshop, 93.3% of the scouts really liked Manufacturing Engineering

workshop, 87.5% of the scouts really liked Computer Science, and 100% of the scouts really liked Science. Students also found the workshops increased their interest in STEM courses.

RAMP Program

An entrance survey and an exit survey were conducted to collect data right before and after students completed the projects to evaluate the content of the workshops. 32 female students participated in the RAMP for High School Girls program in the past two years and took the surveys. Following are the questions students were asked in the entrance and exit survey are listed in *Table* .

Table 3. Survey Questions for RAMP Program

Mechanical Workshop	Electrical Workshop
1. I know.... (a) Nothing about Mechanical Engineering (b) A little about Mechanical Engineering (c) Some about Mechanical Engineering (d) A lot about Mechanical Engineering	1. I know.... (a) Nothing about Electrical Engineering (b) A little about Electrical Engineering (c) Some about Electrical Engineering (d) A lot about Electrical Engineering
2. I know... (a) Nothing about Heat Engine (b) A little about Heat Engine (c) Some about Heat Engine (d) A lot about Heat Engine	2. I know... (a) Nothing about Microcontroller (b) A little about Microcontroller (c) Some about Microcontroller (d) A lot about Microcontroller
3. I know... (a) Nothing about the strength of materials (b) A little about the strength of materials (d) Some about the strength of materials (d) A lot about the strength of materials	3. I know... (a) Nothing about computer programming (b) A little about computer programming (c) Some about computer programming (d) A lot about computer programming

From the survey results before and after Mechanical Engineering workshop, students who thought they knew some/a lot of Mechanical Engineering increased from 6.25% to 56.25%. Before and after Electrical Engineering workshop, students who thought they knew some/a lot of Electrical Engineering also increased from 6.25% to 56.25%. Students reflected that they enjoyed the experience very much and found the workshops to be extremely helpful in helping them to further identify their college interests and majors.

STEM Program for Female High School Students

14 freshman and sophomore female high school students participated in this new STEM program last year. A survey was conducted after the program and asked students about the comments and

suggestions about the workshops. Students were excited about our program and we got positive feedback from the students. “This is amazing!”, “The best event ever!”, “It is fun”, “I loved every workshop!”, “This program is awesome!”, “Thanks everyone for your wonderful work!!!”. Students reflected that they would like to participate in more STEM related activities in the future. Many students were interested in our "RAMP program" which is for junior and senior high school girls.

Discussion

After running STEM programs for many years, we observed there are some key factors affecting the quality of the STEM program.

Volunteers

Faculty is a key factor, both creating the workshop and implementing it. The same faculty members are involved with these three programs. They also train the student volunteers to run the workshop smoothly. Since most of the STEM program participants are female, SWE members play role models in those events. Most SWE members are enthusiastic in promoting STEM to young girls and high school students. Depending on the number of participants, the number of volunteers varies. For the Girl Scout events, we typically need more than 30 volunteers, so planning ahead to make sure we have enough volunteers is key to success. SWE organize the annual Girl Scout event, most volunteers are from SWE club, there are some other professional clubs on campus to help out as well. For example, society of manufacturing (SME) members help with the manufacturing workshop. The other two STEM events are organized by the university (RAMP) and authors (High School) and most student volunteers are from SWE club.

Facility

All STEM events discussed here were held on the university campus. Participants can explore the college environment, fully use the equipment at different labs and introduce the female students to real machines, enhancing their interest in STEM.

Conclusions

Our university collaborated with local organizations and schools to develop three programs. We were motivated to expose young girls and high school students to STEM fields, boost interests and give them more hands-on experience. These experiences could contribute toward the long-term objective of recruiting more female students into the STEM-related educational pathways and careers ^[14].

The experience gained from our STEM programs will help develop even more workshops and activities in the future. These shared experiences should also benefit other educators and researchers with the common goal of increasing the number of female professionals in the STEM fields.

Our future direction would be to track the number of students who enroll in STEM fields after they finish the series of STEM Program for Female High School Students.

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