STEM Program for Female Students during COVID-19 Pandemic

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Abstract

Despite helping to solve problems in society and the environment and enabling financial independence, a disproportionately low number of women enter engineering careers. Contributing factors may include a lack of female role models and activities that would increase the interest and confidence in STEM pathways during the developing years. Our university has initiated activities to provide exposure to role models and STEM activities to young females. This year Ron Burton Training Village (RBTV) started a new STEM program for female students grades 6-11 which would span over 6 years. The students would attend a different experience every weekend and conclude the yearly experience with a capstone project. Our university partnered with RBTV for one weekend workshop experience. The program was intended to be an in-person event but due to the COVID-19 pandemic, this program was conducted synchronously through Zoom virtual meetings. Our university is well known for “hands-on” learning, and we decided to keep the experience hands-on even if it had to be virtual. Students participated in STEM-related hands-on projects, connecting them to real life applications and boosting students' interests in different STEM disciplines. The program represents part of our university’s ongoing efforts to interest young women in STEM.

The core of the half-day workshop was three 45-minute STEM modules: Civil Engineering, Electrical Engineering and Computer Science. The students rotated between the different workshops. The three modules are presented in this paper. Civil Engineering project was Soil Testing, Electrical Engineering project was Food Battery, and Computer Science project was Smart Picker.

38 female students participated in this new STEM program. A survey was conducted at the end of the event to evaluate the content of the program. Students were excited about our program, learning, and experiencing different fields of engineering. We received very positive feedback from the students. The students really enjoyed the hands-on experience. Students reflected that they would like to participate in more STEM related activities in the future.

Introduction/Background

Nowadays, more and more scientists, engineers and innovators are needed to succeed in the global competitive economy environment. As a result, this requires quality science, technology, engineering, and mathematics (STEM) education. International indicators report that US students exhibit a low level of performance in mathematics and science [1]. In addition, there has been witnessed a decrease in the number of graduates from STEM fields [1]. 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 workforce entries. It initiated the “Educate to Innovate” program in 2009 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. Statistical data show there is a substantial gender gap in the STEM fields in workplaces. It has been found that women make up 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 encourage female students to enter STEM fields [2]. In addition, different strategies have been 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 into the STEM fields [7-8] appear to be effective ways to retain female students in STEM.

This year Ron Burton Training Village (RBTV) started a new STEM program for female students grades 6-11 which would span over 6 years. The students would attend a different experience every weekend and conclude each yearly experience with a capstone project. Our university partnered with RBTV for one of the weekend workshop experiences. The program was intended to be an in-person event but due to the COVID-19 pandemic, this program was conducted synchronously through Zoom virtual meetings. Our university is well known for “hands-on” learning, and we decided to keep the experience hands-on even if it had to be virtual.

The weekend experience aimed to help female students explore STEM fields. There were 3 different modules: Civil Engineering, Electrical Engineering, and Computer Science. The students explored a different STEM module for 45 minutes each during the half day program. These modules were led by faculty from different departments and presented by undergraduate students from the respective majors. A group of 12-15 female students would participate a workshop. Besides the faculty member, 2-3 college student volunteers helped. The student volunteers played a large role in the girls’ experience with the activity. The student volunteers explained the activity and acted as role models. During and after the activity, the female students usually asked many questions of the student volunteers.

This paper presents our study with the Civil Engineering, Electrical Engineering, and Computer Science workshops, including preparation, implementation, survey data, observations, and findings.

**Workshop Implementation**

The theme of the RBTV program this year was “Food Security.” In line with this theme the authors designed the three modules. Civil Engineering module was Soil Testing which would help the students understand how to identify what should be planted in which soil to get the best crop yield. Electrical Engineering module was Food Battery which would help the students understand that a vegetable not only provides energy to our body it also can produce electrical energy to power a digital clock or light on a LED light. The Computer Science module was Smart Picker which incorporates advanced technologies that can be used to reduce food waste.
Module 1: Soil Testing
The soil needs to be able to provide nutrients to plants and allow plants to take up the nutrients from the soil. Otherwise, the plants just will not grow well. Students will use material found in the kitchen to test the properties of the soil.

List of material for this module include:
- About half cup white Vinegar (If vinegar is not available lemon juice can work)
- About half cup baking soda
- About one cup water
- A few bowls/cups/plates to mix the soil
- Mason jar (If mason jar is not available, any bottle/cup would do. It just needs to be transparent)
- One spoon
- Ruler (or tape measure)

This activity can get a little messy so you should keep some paper towels or tissues close at hand.

In addition, if students have any seeds (like lettuce, peppers, pumpkin, tomato or any type of flowers), bring some to the session. We will check if the soil samples are appropriate, and you can plant the seeds in leftover soil. This can even be done after this day’s experience.

The pH Test for Soil Acidity or Alkalinity
1. Place 2 tablespoons of soil in a bowl and add ½ cup vinegar. If the mixture fizzes, you have alkaline soil.
2. Place 2 tablespoons of soil in a bowl and moisten it with one tablespoon of water. Add ½ cup baking soda. If the mixture fizzes, you have acidic soil.
3. If the soil does not react to either test, the soil has a neutral pH which is 7.
4. A very high or very low soil pH may result in plant nutrient deficiency or even toxicity.
5. A pH value of 7 is neutral; microbial activity is greatest and plant roots absorb/access nutrients best when the soil pH is in the 5.5 to 7 range.
6. Once you figure out your soil pH, you can change or adjust it. Acidic soil (with pH less than 7) is called “sour” and can be counteracted by applying finely ground limestone. Alkaline soil (with pH greater than 7) is called “sweet” and is treated with ground gypsum which contains sulfur.

Module 2: Food Battery

In this module, students use food to light an LED clock (LED light) as they learn how a battery works in a simple circuit and how chemical energy changes to electrical energy. As they learn more about electrical energy in other ways, they better understand the concepts of voltage, current and resistance \[^{[12]}\]. This module is based on the hands-on activity: “potato power” developed by Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder. The setting for the food battery is shown in Figure 2.

List of materials for this module include:

- A fruit battery kit (Kit A or Kit B) mailed to all participants.
  - Kit A: 1 digital clock, 4 copper sheets, 4 zinc sheets, 1 electronic clock, 1 RGB LED, 4 wires, 2 wires with alligator clips.
  - Kit B: 4 pennies, 4 zinc nails, 2 RGB LEDs, 5 alligator clips.
- 2 large potatoes (fresh) or 4 medium potatoes (fresh). If no potatoes are available, a citrus fruit such as lemon, lime, and orange can be used. This is prepared by participants.

Procedure to create energy

1. If 2 potatoes are prepared, cut each potato to half.
2. Carefully place the zinc sheets (or nails) and copper sheets (or pennies) into the potato. Make sure the two different metals do not touch each other in the potato (see Figure 2).
3. Connect a wire to the end of copper sheet in 1\(^{st}\) potato piece with zinc sheet in the 2\(^{nd}\) potato piece.
4. Repeat step 3, connect the 2\(^{nd}\) potato piece with the 3\(^{rd}\) potato piece, until they are all connected.
5. Connect one alligator clip to the zinc sheet (or nail) in the 1\(^{st}\) potato piece and another alligator clip to the copper sheet (or penny) of the 4\(^{th}\) potato piece. (Figure 2).
6. Connect the digital clock, LED light as shown in Figure 2.
Module 3: Smart Picker

Students will learn about the fundamentals of “Machine Learning” via the use of Teachable Machine, a web-based program developed by MIT to facilitate the building of machine learning models. This module is developed to incorporate machine learning and multiple senses of the students to reinforce their learning. Thus, students will learn how machine learning works by creating hands-on and projects with machine learning models.

Smart picker module has two parts. In the first part, students will take photos of different foods with their mobile devices. The photos should cover different categories of food, such as various vegetables, fruits and grains where these photos will be used as train data set. In the second part students will take photos of themselves making different facial expressions to incorporate multiple senses and label each sense accordingly. Like the first part, photos of facial expressions will be used as training data set.

Part 1 of Module 3

Students should take the needed pictures before the event. This can be done at a grocery store or just around the kitchen. All pictures should be downloaded to the laptop in 3 different folders:

- Pictures of vegetables
- Pictures of fruits
- Picture of grains

Students should generate different folders, which are named as classes in Teachable Machine, for each category. First, the students train their model and then move to the testing. In Figure 3 steps of the machine learning process are presented in details.
Part 2 of module 3

Students should make different facial expressions, mad face, happy face, sad face, surprised face and etc. and record them in Teachable machine platform. Each expression will be categorized and will be used for data training.

As in part 1, data training will be followed by data testing. They will test “machine learning module” by showing different pictures to the computer and see if machine could identify photo or facial expression, correctly.

The structure of Part 2 is presented in Figure 4. In Figure 4, due to students' privacy, student pictures are replaced with emojis.

Different than part 1, in part 2 cognitive connections are included to reinforce learning. Consistent with our observations, studies show that using multiple senses allows more cognitive connections and reinforces learning and memorizing.
Survey Questions and Results
A survey was conducted to collect data shortly after students completed the program to evaluate the content of the workshop. Of the 38 female students who participated in the RBTV STEM Day this year, 22 took the surveys. The following are the questions presented and responses received from the survey:

1. What grade are you in?

2. What rating would you give today’s event?

3. Think back on your day, check the box that best completes the sentence. My confidence in problem-solving...
Based on the survey, 86.4% of students rated our event excellent/very good. 68.2% of the students thought their confidence of problem-solving improved, and 86.4% of students very likely/somewhat likely recommended this event to friends. We also asked an open question: what did you like most about the event today? Many of them said they liked them all, some pointed out one particular activity that they like.

**Discussion**

Due to the COVID-19 pandemic, all workshop materials were mailed to students before the event. This has been the challenge faced by almost all instructors to make distance learning still “work” for as many students as possible. We realized and agreed that students’ enjoyment is very important. If students enjoy the program, they are more likely to stay active, motivated, and engaged. Our practice to improve motivation and learning is to create application-oriented, hands-on, active-learning opportunities for the students. The students were exposed to aspects of Civil Engineering, Electrical Engineering, and Computer Science, and the survey results indicate that many students enjoyed the hands-on workshops and would recommend the event to others.

**Organizing the workshop**

Organizing these types of workshops is usually time consuming, and making it hands-on in a virtual environment added another layer of challenge as we could not use the lab equipment we would normally have available for tests. The authors' first challenge was to plan the activities which the students could perform safely without needing help from an adult and without any lab equipment.

The next challenge was the cost. Funding is always a problem for outreach activity, and it is even more challenging for virtual events involving hands-on activities. For in-person hands-on activity, students will work as a group and the experiment kits can be shared and reused. However, for a virtual event, each participant needs to have their own experiment kit, so the costs are higher. Premade single use kits can be expensive, and we needed to be mindful of
shipping constraints and expenses. RBTV Village had promised they would collect the kits from
us and mail them to the students. We still could not send any fluids.

Taking all these constraints into account the authors set out to find appropriate activities.
In the soil module, we needed to send acidic and alkaline soil to students. We did not have acidic
or alkaline soil. We could buy neutral soil from the gardening store. So, we added sulphur to half
of the soil to make the soil acidic and garden lime to the other half to make it alkaline. That way,
the students would be able to learn the concepts. We also sent washing soda in a third packet.
The students were asked to buy vinegar since it could not be mailed.

In the food circuit experiment, we were able to find 24 kits. This number was fairly close to the
number of students we were expecting at the event. However when the girls heard about the
hands-on kit and experience, some of them who had gone on a hiatus due to Zoom fatigue,
decided to return to RBTV. We scrambled to find more kits and were able to get them shipped
but these were a little different than the previous kits but it was manageable.

The two kits were put in a gift bag and 40 such bags were given to RBTV. The bags had to be a
size that would fit in a medium sized flat rate envelope.

Through thorough planning, the material was sent to the girls. Unfortunately, two girls did not
get the material till the afternoon of the event. It was disappointing to see them wanting to
participate but unable to fully participate because of the delay in shipping.

The next challenge was the training of volunteer students. The authors encourage undergraduate
students to take the lead in presenting the modules to the girls. Being closer in age, the school
students are excited to learn from the undergraduate volunteers. The authors strongly believe in
the students teaching students approach. Usually, training these students is a quick meeting in the
lab. At this event it was challenging to make sure that the undergraduate students had enough
samples to first try and then present the modules. One student did not get the mail till the night
before and the author had to drive an hour each way to give it to the student at their house. Such
challenges do not occur in the in person events.

Another challenge was keeping students engaged. In order to overcome the zoom fatigue and
make the virtual activity more interactive, we did an ice breaker activity at the beginning of the
event. A word cloud was created and two questions were asked:

- What are your favorite fruits/vegetables?
- What do you see as connections between food and Engineering/Science?

The results are shown in Figure 6. Among those favorite fruits/vegetables, the favorites were:
watermelon, strawberries, and mango. There are many thoughts about the connection between
food and engineering/science. Planting, baking, bioengineering, genetic modification, helping
environment, feeding a population, irrigation, food in security, agricultural tech, making
healthier food, etc. the most popular choices are *cooking, farming, and energy*. Two of these fell into the category of the activity we provided for this event.

Figure 6. Point Cloud results

Students’ disengagement caused the author to modify the activity. In the smart picker experiment, the students were asked to take pictures of fruits. They were not engaged so the author changed it to pictures of facial expressions instead. The students loved making silly faces and using artificial intelligence to understand these expressions.

Since it is a virtual event, participants work on the hands-on activity at their homes. Therefore, keeping cameras on is very important so the instructors/volunteers can see what the students are doing and readily guide them through the activity. However, some girls had their cameras off all the time even we emphasized many times that they need to have their cameras on.

Figure 7. Preparing the material to be mailed out to the students

**Conclusions**

STEM Program with RBTV is motivated by exposing female students to STEM fields, boosting students' interests and giving them actual hands-on experience. Although this program can also
in the longer-term recruit new students into our school, it most importantly fulfills our long-term objective of recruiting more female students into the STEM-related career.

Civil Engineering, Electrical Engineering, and Computer Science workshops were presented in this paper. This virtual event was very successful. Students were more involved since each participant would complete the hands-on activity by themselves. With breakout room setting in Zoom, volunteers could help participants directly in a relatively quiet environment. Positive feedbacks were received by the participants as well as the RBTV STEM event organizers. The survey shows that most participants learned something and enjoyed the activities. It seems that the virtual event is as effective as the in-person, hands-on STEM event.

The experience gained from this program will help us to be more prepared and creative in organizing 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.

Our future direction would be to track the number of students who enroll in STEM fields after they finish the series of STEM Programs for female students.

References:


