Create Interests in Engineering with Girl Scouts

Dimitri Papazoglou, Saneela Rabbani and Shouling He
Vaughn College of Aeronautics and Technology, 86-01 23rd Ave, Flushing, NY
dimitri.papazoglou@vaughn.edu, saneela.rabbani@vaughn.edu, shouling.he@vaughn.edu

Abstract
This paper presents an all-female workshop that exposes girls from ages eleven to seventeen to engineering concepts as well as creating an engineering product. We consider that girls in this age period are crucial as many of them will soon venture into possible career options but aren't always given the proper exposure to engineering. Thinking about most girls' interests in this age group, we introduced the electric circuit that can generate musical notes in the workshop. Music is a means which people of different cultures, backgrounds, and lifestyles can communicate with each other. Through building an electric piano, the girls have learned the basic concepts of engineering and what engineers are working with. By incorporating something that most, if not all people, enjoy. The attendees felt eager and excited to learn about engineering.

While exploring the challenge of selecting a teaching engineering topic to young females, the paper also describes our experience while teaching 125 girl scouts in multiple sessions with a short period of workshop time for each session. There were a total of eight sessions with every session consisting of sixteen girls and a time frame of 45 minutes. Within a session, the girls were not only taught the fundamentals of engineering, such as electrical current, resistance and resistors, and closed-loop circuits, but also were given the time to build a fully functioning electric piano. By the end of each session, the girls were asked questions about what fundamental knowledge they were taught. More than 75% percent of the girls quickly provided the correct answers and even used appropriate technical terminology. Furthermore, the survey and questioning given by faculty and staff showed a lot of the girl scouts clearly expressed their interests in engineering. They want to be engineers in the future. Ultimately, this workshop dismantled any previous impressions of engineering that were exclusive and taught the young and brilliant girl scouts what engineering really is.

Introduction

Research has shown that children decide on subjects they like or dislike as early as elementary school or middle school [1]. Evidence suggests that female students can lose their interests in math and science and eventually choose careers far from engineering around the age of ten to twelve. Results in the ratio between male and female engineers are quite large [2]. Therefore, introducing students to the exciting potential of engineering at an early age is of significance.

A student's choice of an academic track or career in engineering mainly depends on the student having gained positive experience associated with the field during middle school or high school. However, this can be difficult in the United States since engineering courses and the corresponding interactive design projects for practical engineering products are not always included in middle school, even high school curriculum. In this paper, we try to explore the possibility of developing a short-time workshop with an interesting engineering project which can motivate middle or high school female students to learn engineering, and eventually pursue careers in engineering. For the workshop, we need to consider two factors to develop it: (1) the time period allowed for the students to complete the project and (2) the expense of the project

product. The workshop was included in the event, Next Generation Science, Technology, Engineering and Math (STEM) Program, sponsored by Vaughn College of Aeronautics and Technology, for the Girl Scouts of Greater New York Nassau and Suffolk Counties. More than 145 middle or high school girls were planned to attend the event. Since the girls would be separated into multiple groups, with one group having less than 50 minutes in the workshop, the project should be able to be finished within the time period. After a student had built the electric piano, the product would be a gift for her and she would take her electric piano home. Therefore, the product should be relatively inexpensive.

In terms of developing an interesting project for engineering education, a number of research works have reported the approaches and some of the survey results [3][4]. After the study of different engineering projects for the workshop, we decided to build an electric piano and explain the circuit and engineering concepts before the students actually make it. The workshop was successfully held on December 4, 2016. The result was quite remarkable. Moreover, the event allowed us to achieve valuable experience for us to hold similar workshops in the future.

The paper is organized as follows: detailed descriptions for us to choose an electric piano, the procedures of the workshop, which are separated into three parts: Part 1: Introduction to the basic concepts of engineering and circuits; Part 2: Guiding the students to build their own electric piano; Part 3: questions and discussion. The conclusion is provided in the final section.

Developing the Workshop, "Get Noted"

In our effort to enrich the engineering experience, we chose the electric piano to attract and engage the girls scout. Several factors influenced this decision: most people enjoy music. The components to build the piano were easily accessible and readily available and inexpensive. The piano was simple to build.

The Extraordinary Women Engineers 2005 report states that girls believe engineering is for people who enjoy both math and science and that engineering is difficult and challenging [5]. The report also shows that the first words that come to girl's minds when thinking of engineering included men, boys, cars, engines, which are too difficult and boring. We hope that this project would show girls that this is not a field only for boys or men. It is not about only building cars and engines and it is neither too difficult nor boring. We wanted to incorporate a project that involves the students in such a way that they tie engineering to a daily activity they enjoy. In doing so, engineering becomes more approachable and doable.

After brainstorming and researching several engaging daily activities, we concluded music to be the most effective collaboration with engineering. The music industry is one of the largest industries with a net worth of U.S. $130 billion globally. It is no surprise that people all around the world enjoy music. Additionally, music serves as a universal platform to unite people. We wanted to unite the girls in the same fashion.

Furthermore, Neurological Research has shown that early music training dramatically enhances children's abstract reasoning skills. These findings show that music enhances higher brain functions required for science, mathematics, chess and engineering [6]. The various frequencies on the electric piano correspond to the music notes Do-Re-Mi-Fa-Sol-La-Si. Essentially, the

electric piano serves as an affordable and smaller alternative to actual pianos. By building and using it, the girls will simulate different parts of their brains and enhance their abstract reasoning skills in numerous ways. Thus, we chose the electric piano.

All the components were bought online, however if there was a shortage of any component, they could easily be found at local stores like RadioShack or Microcenter. The electric piano cost $10 per student. This extremely affordable and allowed us to teach and impact a large number of females. Also, if the girls wanted to recreate the pianos with others, they would not be held back due to accessibility or cost.

Lastly, the electric piano did not require complex assembly. Although all of the components utilized were basic electrical components, they are used in industrial applications of various difficulty levels. This way, we expose the girls to real components and expectations of industrial engineering. The instructions on assembly and utilization of the components are clear and concise, allowing for a more efficient and productive use of the limited time we had. This also permitted the girls to spend more time on the hands-on building and troubleshooting.

Holding the Workshop

The girl scouts are put into an environment they are unfamiliar with, thus creating an atmosphere where learning can be difficult. The most logical step is to break the ice as soon as possible. Since time is limited, we had to expose the girls to a fun and comfortable environment in order for them to be truly interested. Our first step is not only to introduce ourselves in a fun and welcoming way, but to introduce the purpose of The Society of Women Engineers (SWE). This introduction presents the girls with a problem. The problem is that there are not enough women interested in engineering and that the reason they are here today is to be exposed to engineering.

The workshop has been organized in three sessions. The first introduces the students the basic concepts of engineering and circuits. The second permits students to assemble the electric piano by themselves. After they have effectively built and troubleshoot the circuit, the floor was open for questions from us and the girls alike. The three sessions are detailed as follows.

1. Introduction to Engineering and Circuits

Of the three sessions, the most important is the introduction presenting the electric piano. For this session, the following concepts were discussed.

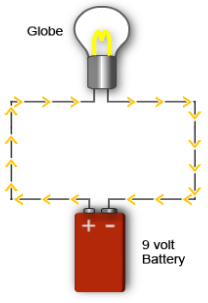


Figure 1: Current Flow

(1) Current flow

Current flow is important due to the electric piano having all electronic components. In order for electricity to flow, you need current. This is important to the girl scouts as it dismisses a great deal of mysteries of how electricity works. Conduction in electricity occurs when a material such as copper or aluminum has electrons flow through it, unlike wood or plastic. A great way to explain current flow is with a battery and a light bulb. The visual of current going from a positive battery terminal through the light bulb and leaving through the negative terminal allows the girls to see the concept of current flow.

(2) Resistors and Capacitors

The second step is to explain the electrical components of the electric piano. Resistors are the most common components in this project. Explaining that the purpose of this component is to limit current was well understood. The colorful bands on the resistors stand for the quantity of resistance in a resistor which is labeled in OHMs. We briefly introduced the capacitor; we only explained that it stores energy, builds charges and then releases them in relation to the 555 timer. There could have been more info on the capacitor, but due to the limitation of time, it was not given.

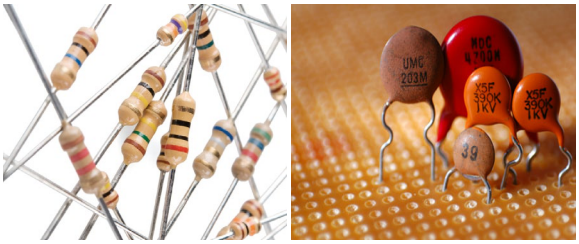


Figure 2: Resistors (Left) and Capacitors (Right)

(3) Switches

The switch was best explained with a physical presentation. When you activate a switch, the circuit opens and current is not flowing through the circuit or device. When you turn off the switch, current flow is active, thus enabling the device on. Turning off the lights in the room and asking the students if current is flowing is a good way to embed this information on switches in their mind.

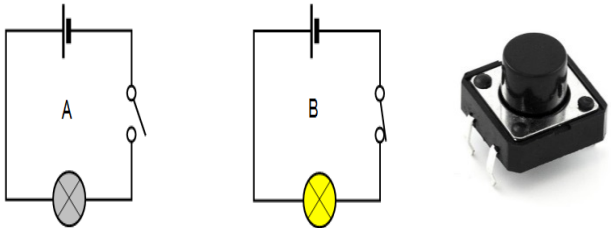


Figure 3: Switch Circuit and Switch

(4) 555 Timer

The heart of the electric piano is the 555 timer. Figuring out how to explain an integrated circuit was one of the most difficult aspects of this workshop. We displayed the pin layout of the IC chip to show that each pin has a function. We explained that the chip produces frequencies in use with the different resistance values and capacitor values. The introduction of mathematics is an extremely vital part. The following mathematical equation can be used to shed new light for the Girl Scouts to understand how the different frequencies are generated. Mathematics isn't just about adding up the amount of money spent or counting the number of apples left in a basket, but also calculating a frequency and then generating a tone through a speaker.

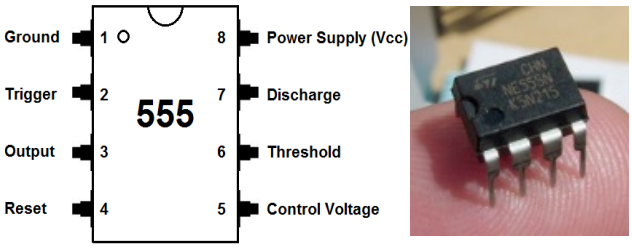
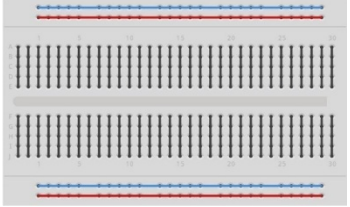


Figure 4: 555 Timer: an Integrated Circuit (IC) Chip.

$$frequency = \frac{1}{.7(R_A + 2R_B)C} \quad (1)$$

(5) Breadboard

The breadboard is a main component in our workshop. It holds all the components mentioned above. Each vertical column is in



series connections. This image's purpose was to clarify how to wire the components in series connections, using the breadboards pre-connected layout.

Figure 5: Breadboard

2. Assembling the Electric Piano

After the ten minute introduction of the electric piano, the girl scouts were static and eager to learn how the electric piano works and how to build it. Based on the lecture presented in the previous session, each girl got an assembly instruction sheet, which included the circuit layout and component explanations and a plastic bag, which contains all components necessary to build the electric piano. The fully functioning electric piano is shown in Figure 6.

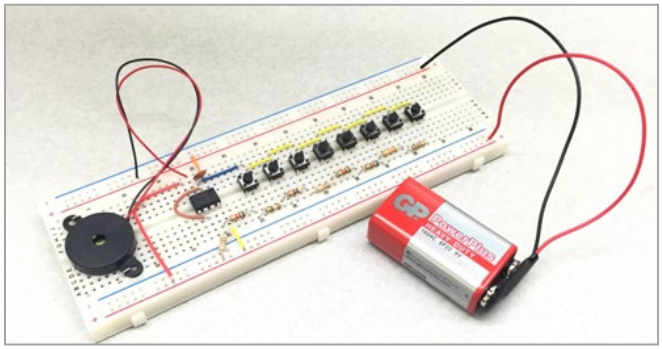


Figure 6: Electric Piano

Figure 7 demonstrates how the female students worked under the guidance of the SWE members and other workshop leaders. When students needed help, there was always an instructor available to facilitate with the building process. Most students completed with the building and troubleshooting within 30 minutes. Students were very satisfied with their accomplishment. During the lunch period, the cafeteria resonated with different musical tones.

3. Questions

During the last five minutes of every workshop session, a number of questions were asked to verify the students learning results and retention. The questions are:

a. When we turn off the light, is there current flowing through the lights?
b. When the switch is in the off position and the light is off, is the circuit open or closed?
c. What is the purpose of a resistor?
d. What function does the 555 timer serve in this piano?
e. What is frequency? How would you describe it in your own words?

The answers that we received from the students were very satisfactory. There were approximately 18 students in each workshop session. More than 12 students, on average, actively answered the questions. Their answers were very impressive. Some of them surprised us by using technical jargons. For example, a response to the question for the definition of frequency, one girl answered "The number of waves in a period." We also received positive feedback from the students who stated that they would like to have more workshops that expose and engage them in the engineering field.

Figure 7: Under Guidance of SWE Members, the Girl Scouts Assemble Their Electric Piano

Conclusion

In this paper, we discussed how to develop a workshop for middle to high school female students to learn engineering and how the knowledge of engineering can be used to make a product. The students were challenged to build an electric piano to enhance their hands-on and technical experience. Meanwhile, we tried to show students how to effectively manage time for an engineering project. Students were able to keep the pianos they built and the detailed packet to rebuild and challenge their family and friends to do the same. As a result of the workshop, the girl scouts felt empowered, and were inspired to possibly pursue a future career in engineering.

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