Proceedings,
The 2013 ASEE North Midwest Section Conference,
October 17-18, 2013, Fargo, North Dakota.

ASEE-NMWSC2013-0012

Addressing Early the Gender Gap in Electrical Engineering via Summer Camps for Girls

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Abstract

We describe the design, implementation, and outcomes of the Women in Electrical Engineering (WEE-GIRLS) camp for middle-school girls organized at North Dakota State University. The camp is motivated by the low representation − approximately 10% − of women in electrical and computer engineering fields. Its goal is to address this gender gap problem by exposing women to electrical engineering at an earlier age, thereby fostering excitement about pursuing careers in electrical engineering and higher confidence in their math, science, and problem-solving skills. Designed for the duration of one week, the camp activities include hands-on microcontroller based projects using Arduino boards, class discussions, meetings with female professors and students, and tours of local high-tech companies. Utilizing entry and exit questionaires, we found that 50% of the participants felt empowered and declared that they wanted to become electrical engineers. We also discuss several suggestions for improving future editions of the camp.

Introduction

According to the National Council for Research on Women (NCRW), women constitute 45% of the workforce in the U.S., but hold only 12% of science and engineering jobs in business and industry[1]. This situation is expected to get worse because, according to the U.S. Labor Statistics, more than 75% of tomorrow's jobs will require use of computers, while fewer than 33% of participants in computer courses and related activities are women[2]. Even though undergraduate enrollment rose by 19% from 2000 to 2007 and there were relatively larger gains in female enrollment (8.9 million female vs. 6.7 million male in 2007), the percentage of bachelor's degrees in engineering and engineering technologies awarded to women is only 17%[3]. Moreover, among all engineering fields, electrical engineering has one of the largest gender gaps. That is, the women's representation in electrical and computer engineering fields is only 10% compared to for example 35% in chemical engineering[4].

In order to improve the situation of women in electrical and computer engineering fields, we designed and organized a summer camp for middle school girls enrolled in grades 6-8 (11-13 years of age). This is part of a three year educational and outreach plan supported by a National Science Foundation award. The first edition of this camp was held in 2012 in the Department of Electrical and Computer Engineering (ECE) at North Dakota State University (NDSU). In this paper, we present details about the first edition of this project and discuss some of its findings. Furthermore, we present some new ideas that we plan to pursue in the future editions of this camp (the second edition will be organized in 2014).

Description of the Summer Camp

The WEE-GIRLS summer camp is designed for one week. During a typical day (9am-1pm) in this program, students attend class discussion, perform hands-on activities and projects, meet female students in the Electrical and Computer Engineering (ECE) Department, hear various speakers, and tour NDSU labs and local high-tech companies. Guest speakers of this program include members of the FORWARD (Focus on Resources for Women's Advancement, Recruitment/Retention, and Development) Program at NDSU[5], other nationally renowned women in electrical engineering, and current or recent female ECE graduates. These speakers are invited to talk as role models about empowering women in science, technology, engineering and mathematics (STEM). The objective of this camp is that by exposing women students to electrical engineering at an earlier age, they will become more interested about pursuing electrical engineering and more confident in their math, science, and problem-solving skills.

When developing the above activities, we focused on capitalizing on three psychological processes: 1) increasing perceived self-efficacy in the domain of electrical engineering by providing camp participants with an opportunity to successfully complete small-scale projects; 2) increasing interest and perceived self-efficacy by providing camp participants with positive models that have succeeded in the field of electrical engineering; and 3) increasing interest and positive attitude toward electrical engineering through engagement in fun activities. We discuss these three psychological processes below.

1) Increasing perceived self-efficacy through self-achievement: In Bandura's social cognitive model of self-efficacy, self-efficacy is defined as, "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances"[6]. In his view, perceived competence includes both behavioral actions and cognitive skills necessary for performance in a specific domain. "Perceived self-efficacy refers to belief in one's power to produce given levels of attainment"[7]. According to Bandura, the individual's perceptions play a key role in this process - especially the perception that there is personal efficacy in exercising influence over what they do and what happens to them. Researchers have consistently demonstrated that self-efficacy predicts students' mathematics performance[6,8]. *In this camp, we increased perceived self-efficacy by engaging participants in activities at which they can succeed.*

2) Increasing perceived self-efficacy and interest through role modeling: Role models are individuals you respect, follow, look up to or want to be like. Bandura's Social Learning Theory proposed that one way children learn is by observing and experiencing the behavior of others, particularly of same gender adults[6]. This theory has thus important implications for the essential role of positive same-gender models in youth's career development[9]. Indeed, extensive research has shown that children's and adolescents' relationships with significant adult others contribute to their identity development and foster resilience[10]. Involvement of role models is positively related to youth achievement of career-related outcomes[11]. Role models play a particularly important role in the lives of women due to a lack of female role models in nontraditional careers and the existing gap between the numbers of men and women in STEM careers. This gap between genders, which begins in adolescence, is mostly due to girls' awareness of typical gender stereotypes regarding math ability and the resulting decrease in their interest and confidence in math and science[12]. One promising approach in combating these types of gender stereotypes is the use of female role models. One study by Holmes et al.[12] found that an after school mentoring program focussing on engineering topics increased girls' self-confidence in math and science. *In this camp, we fostered high levels of perceived self-efficacy and interest in electrical engineering by exposing camp participants to successful same gender role models.*

3) Increasing interest and positive affect through task engagement: According to the flow theory of motivation[13], a flow experience is a mental state in which an individual feels completely immersed in the task or activity at hand. Prior work indicates that maximum level of interest positive affect is achieved by moderately challenging tasks that match the person's abilities. Specifically, in a study conducted with middle adolescents across the U.S., Shernoff et al.[14] found that participants experienced increased engagement when the perceived challenge of the task and their own skills were high and matching, the instruction was relevant, and the learning environment was under their control. Participants were also more engaged in individual and group work versus listening to lectures or watching videos. *In this camp, we increased interest and positive feelings about electrical engineering activities by engaging camp participants in challenging and fun hands-on activities that were moderately challenging.*

The agenda with all activities of each of the five days of the WEE-GIRLS 2012 is shown in Table 1. The hands-on projects focus on electrical and computer engineering topics and are initially designed for 6 girls. These girls were recruited from schools in the Fargo area (but the long-term objective is to also recruit students from rural areas of North Dakota). As seen in Fig.1, the six participants formed a diverse group.

Table 1: Agendas with all activities during each of the five days of the WEE-GIRLS summer camp of 2012.

Days	**Activities**
Day 1	Entry questionnaire, Tour of Dept. of ECE, What is a microcontroller? Intro to development board and programming in C, Project 1: Blink LED
Day 2	Project 2: Control patterns - array of LEDs, Tour of NDSU campus Tour: Phoenix International[15]
Day 3	Photo shoot: Group photos, Project 3: 7-segment LED dice FORWARD faculty member presentation (Prof. Kalpana Katti's lab)
Day 4	Project 4: Tune player, Assistant: Whitney C. (recent ECE graduate) Tour: Packet Digital[16]
Day 5	Tour: Appareo Systems[17] Project 5: Lie detector, Assistant: Courtney B. (current ECE graduate) Exit questionnaire

Description of the Microcontroller Projects

In this section, we present specific details about the hands-on microcontroller based projects − the main activities during each of the five days of the camp. These projects are adapted from Monk (2010)[18]. While their description is done in layperson's terms, they are exciting (as they are designed around LEDs and audio) yet challenging (because students

(a) (b) (c)

Figure 1: (a) The six participants of WEE-GIRLS 2012 and the first author (holding letter "G"). (b) Listening to prof. K. Katti while touring one of her research labs. (c) Snapshot of participants using Arduino boards during one of the hands-on projects.

are given assignments to be solved at the end of each project). Below is a listing of these projects.

Project 1: Blink LED - This project introduces the Arduino development board[19] by controlling a simple light emitting diode (LED) to make it blink on and off. Students are introduced to the concepts of LEDs and resistors as well as to C-like programming. The project assignment requires students to modify the Arduino program (referred to as a sketch) in order to make the LED blink faster.

Project 2: Blink 1234 - This project builds on the concepts learned in project 1 by continuing to work with a linear array of four LEDs that are turned on and off in different styles to create various visual effects. It reinforces the concept of resistor utilized to limit the size of the current through LEDs. In addition, it introduces the concept of programming variable utilized to refer to one of the Arduino board's pins inside the sketch. The assignment invites students to create their own style of blinking the LEDs in the array.

Project 3: 7 segment LED die - 7-segment LED displays are introduced in this project. Students implement a simple die, which can be "tossed" by pressing a push-button while the random number between 1 and 6 is "displayed" on a 7-segment LED. By focusing on more complex LEDs, this project introduces the concept of random numbers. Push-buttons are utilized for the first time too. The assignment requires students to modify the sketch to display randomly one of the following letters A, C, E, F, L, U instead of a random number between 1 and 6.

Project 4: Tune player - A series of musical notes are played via a buzzer to compose a jingle. Students learn how to generate "approximate" sine waves and how to utilize a simple digital-to-analog converter (DAC) constructed with a R-2R resistor ladder. The concept of binary numbers is also introduced. As a project assignment, students must modify the Arduino sketch to compose and play a different song.

Project 5: Lie detector - As a final project, students build a simple lie detector. The lie detector is based on an effect known as galvanic skin response (GSR). As a person becomes nervous - for example, when telling a lie - the skin resistance decreases due to an increase in the moisture level of the skin. The lie detector is based on measuring the resistance of the skin. This resistance is measured via an analog input of the Arduino board and an LED and buzzer are utilized to indicate a lie. Students then form pairs of two and test each other by answering different true or false questions.

The detailed description of each of these five projects can be downloaded as pdf files from the webpage that we maintain for this program[20].

Results and Discussion

In this section we present and discuss the data that we collected via the entrance and exit questionnaires. These questionnaires are designed to capture participants' well-being and knowledge about engineering on the first day and to capture the feelings or attitude toward electrical and computer engineering on the last day of the camp. The questionnaires are included in the Appendix at the end of this presentation.

By utilizing a scale from 0 to 5 (as explained in the Appendix), we plot the answers to all questions from the exit questionnaires in Fig.2.

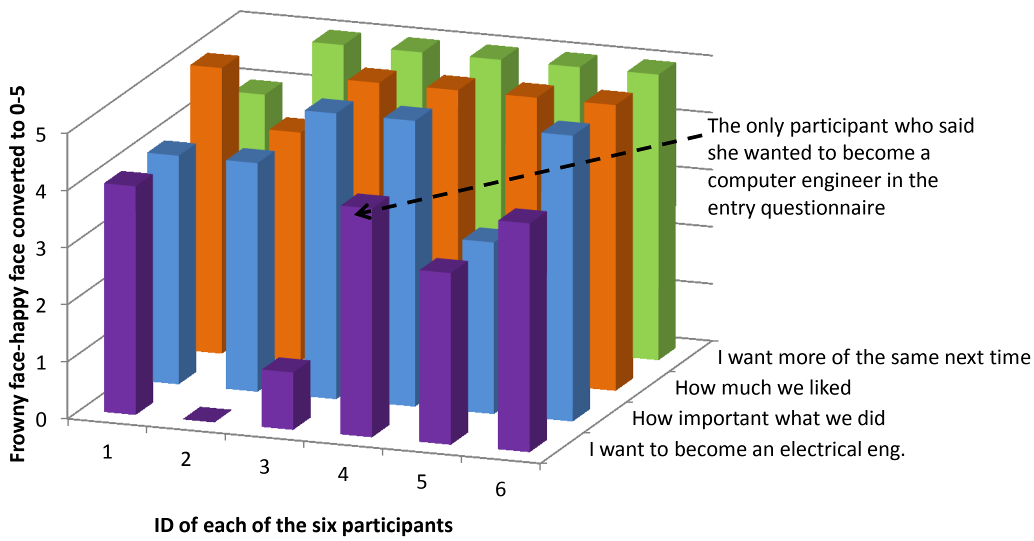

Figure 2: Answers of all all six participants to the questions from the exit questionnaire.

The most important aspect of these results is that, at the end of the camp, four out of six participants reported scores of 3 (one participant) and 4 (three participants) suggesting strong interest in becoming an electrical engineer. We found that one of the six participants answered yes to question 2 of the entry questionnaire ("Is there an engineer in your family?") and that her father was an electrical engineer. The same participant answered that she wanted to become an electrical engineer in the exit questionnaire despite the fact that, in answering question 4 of the entry questionnaire ("What would you like to become or do when you grow up?") at the beginning of the camp, she said that she wanted to become something else. In addition, another one of the four participants who said they wanted to become electrical engineers at the end of the camp, had already answered "Computer engineer" (aside from also becoming a lawyer or a doctor) to question 4 of the entry questionnaire at the beginning of the camp.

Future Camp Ideas

Here, we discuss several ideas, which could be worthwhile to consider in future editions of the camp.

We recruited participants via emails sent to faculty and staff emailing lists at NDSU. Consequently, the chances of attracting participants from families where children have been already exposed to STEM professions were possibly higher. To avoid this in the future, we plan to select participants in collaboration with existing entities engaged in STEM activities. In the case of NDSU, such examples include the Center for Science and Mathematics Education (CSME)[21] and the Governor's School[22]. Such entities or centers have already existing relationships with regional schools, which can help to select participants from poorer families or rural areas whose parents do not have engineering professions.

An enhancement to the current format of our summer camp, which we project would help even more our main goal, is to organize follow-up summer camps (in the following year) with the same participants. Exposing girls repeatedly to engineering concepts will provide the necessary reinforcement of the main topics and will foster the desire to pursue engineering careers. In addition, it is also desirable to maintain a database of participants and their contact info (with parental consent) to keep track of their careers later in their lives. Such data would present concrete statistics about how many participants will eventually pursue careers in engineering.

To measure the improvement in perceived self-efficacy, we plan to update the exit questionnaire with an additional question, "I believe I can become an electrical engineer". We also plan to increase the number of participants to 12. This number of participants is still manageable by two coordinators (organizer plus assistant) and will help to increase diversity in group based projects and to improve the overall dynamics of activities.

Related Work

The idea to teach and share the fun of STEM in general and engineering in particular to girls is merely new. Similar efforts, under the form of technology camps, workshops, or TV shows have been organized in the past. Examples of such programs include GAMES at Illinois[23], GROW at Kansas[24], BrainCake at Carnegie Science Center[25], and SciGirls at PBS Kids[26]. Additional examples or summer camps (past and present), listed by state, can be found on the websites of various educational organizations[27,28]. While these programs target both middle school and K-12 students, very few report qualitative assesments of the impact of their efforts as we do in this paper. In addition, our camp was the first one to focus on electrical and computer engineering in North Dakota.

Conclusion

To address the low representation of women in electrical and computer engineering, we developed and organized a summer camp for middle-school girls at North Dakota State University in 2012. In this paper, we presented the design, implementation, and outcomes of this program. While we have identified a few aspects that can be improved, the data collected via the entry and exit questionnaires make us believe that the summer camp was a successful step towards the goal of encouraging girls to consider STEM careers.

Appendix

The entry and exit questionnaires completed by each of the six participants on the first and last days of the summer camp are shown in Fig.3. The scale "frowny face"-"happy face" utilized in these questionnaires is converted into a scale 0-5 by partitioning the "frowny face"-"happy face" line into six intervals, which are labeled with numbers from 0 to 5. This new scale is utilized in the plot from Fig.2.

Acknowledgment

This effort was supported by the National Science Foundation (NSF), as part of the educational and outreach plan of a grant (CCF-1116022) awarded to the first author. Any findings and conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the NSF. The authors also thank the Dept. of ECE at NDSU for providing the lab space and facilities, to prof. Kalpana Katti for the presentation and tour of her research labs, to the engineers at Phoenix International, Packet Digital, Appareo Systems for their presentations and tours, and to Whitney Conmy, Courtney Becker, and Nancy Rossland for their assistance. Finally, many thanks are due to the six participants who made WEE-GIRLS 2012 a fun and rewarding experience.

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2012 WEE-GIRLS Summer Camp (ECE, NDSU)
Entry Questionnaire

Select a number between 1-100 (remember it):__________________________________

How are you doing? How are things going in your life? Please make a mark on the scale to let us know. The closer to the smiley face, the better things are. The closer to the frowny face, things are not so good.

Me
(How am I doing?)

I--I

Family
(How are things in my family?)

I--I

School
(How am I doing at school?)

I--I

Everything
(How is everything going?)

I--I

(a)

1. Do you know what an engineer does? If yes, please answer in just a sentence.

2. Is there anyone in your family an engineer? If yes, do you know what kind of an engineer?

3. Have you ever thought about or wanted to become an engineer? If yes, what kind of an engineer?

4. What would you like to become or do when you grow up?

(b)

2012 WEE-GIRLS Summer Camp (ECE, NDSU)
Exit Questionnaire

What number between 1-100 did you select on Monday?______________________________

How did you like the WEE-GIRLS Sumer Camp 2012? Please put a mark on the lines below to let us know how you feel.

What we did and talked about was not really that important to me. — **How Important** — What we did and talked about were important to me.

I--I

I did not like what we did. — **What We Did** — I liked what we did.

I--I

I wish we could have done something different. — **Overall** — I hope we will do more of the same next time.

I--I

I now desire less to become an electrical engineer. — **Want to Become an Electrical Engineer** — I want to become an electrical engineer.

I--I

(c)

Figure 3: (a) The first page of the entry questionnaire. (b) The second page of the entry questionnaire. (c) The exit questionnaire.

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