122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #12235

Implementing and Evaluating An E-Textile Curriculum In an Engineering Summer Program for Girls (Evaluation)

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Abstract

This paper addresses the implementation and assessment of an e-textiles curriculum in a summer STEM program for girls. The goal of this residential, five day camp is to help girls learn about STEM subjects and introduce them to careers involving STEM. Girls completing 6th grade or 8th grade can attend the program. Variations of this program has been offered for 15 years and have reached over 3,000 girls. The new curriculum, using e-textiles, was implemented in the summer 2014 program. The evaluation of the curriculum was done through observations of the e-textile sessions, feedback from the participants, and information gathered in participant's engineering notebooks. The evaluation offered is primarily anecdotal, though participant feedback and notebook analysis is compiled into quantitative data. While the overall feedback on the e-textile projects was positive, the girls exhibited some displeasure at having sewing be part of the project. We present the results of this evaluation, as well as a discussion of the lessons learned through the design, implementation, and assessment process of this program.

STEPS Camp at the University of St. Thomas

The STEPS (Science, Technology, and Engineering Preview Summer) program at the University of St. Thomas (UST) is a five day long residential camp for girls. The goal of STEPS is to get girls to learn about STEM subjects and introduce them to related careers. Two types of STEPS camps are offered: Basic and Advanced. Girls completing 6th grade attend Basic camp while girls entering 9th grade who previously attended Basic camp, attend the Advanced camp. The UST

STEPS camp is based on the STEPS camp developed at the University of Wisconsin-Stout, which began in 1997.

Students participating in the camp explore various aspects of STEM through hands-on classes, attending discussions/panels on engineering, and working on projects. Campers also engage in recreational activities such as movies, athletics, and exploration of the university campus. For the past fourteen years of STEPS at UST the main project for the Basic camp has been the building of a remote-controlled airplanes that would be flown on their last night at camp. After panel interviews with past STEPS participants it was decided that a new project would be introduced for the 2014 camps.

One goal for the new project was that it **be functional once the girls brought it home**, unlike the plane (for which the power source and controller were only lent to the girls for the duration of camp.) A second goal was that the project **allow for unique solutions and personalizatio**n, such that the girls had multiple chances to make design decisions. Finally, we wanted a project that would **allow for discussion of the ways engineering could make a positive impact on people's lives**.

Incorporating E-textiles into STEPS

As part of the curriculum redesign process, a literature review was done to see what sort of projects and topics have been shown to be effective in engaging girls with engineering and computer science. E-textiles, the incorporation of digital components and electronics into fabric, typically through sewing with conductive thread, has been used in numerous programs designed

for girls, with favorable results[2,5]. In comparison to classical methods of introducing circuits and their components, e-textiles allow for all of the pieces to be seen allowing for a clearer understanding of the components[3]. The materials used in e-textile projects can inspire more questions among the participants as thread and fabric are familiar objects to. With wires, especially insulated wires, there are few things that are interacted with daily that are similar to these materials to inspire further exploration in the learner[1]. Sullivan argues that solving functional design problems helps learners to continuously circle through the Engineering Design process when projects fail to work as intended by making observations and hypotheses and then testing these hypotheses and evaluating the outcomes[7].

Based on the above findings, it was decided that an e-textile project would be introduced to the STEPS camp for the first time in the summer of 2014, and that it would replace the plane project as the signature project for that year's camp. In addition to using this as a way to teach about circuits, it was also acknowledged that through a fabric project, topics such as geometry and 2D/3D forms could also be explored. There was to be a slight variation in the difficulty and scope between the project the Basic and Advanced campers encountered. However, both groups were to be given the same initial introduction to electronics and e-textiles.

Introduction to E-Textiles (Basic and Advanced Camp)

In both Basic and Advanced STEPS, the girls were given a short introduction to two different applications of e-textiles, the first being a pair of shoes that utilized GPS to help visually impaired walkers to find their way home by having the shoes vibrate to indicate the direction to take, and the second example being a fabric that was sewn in such a way that as someone

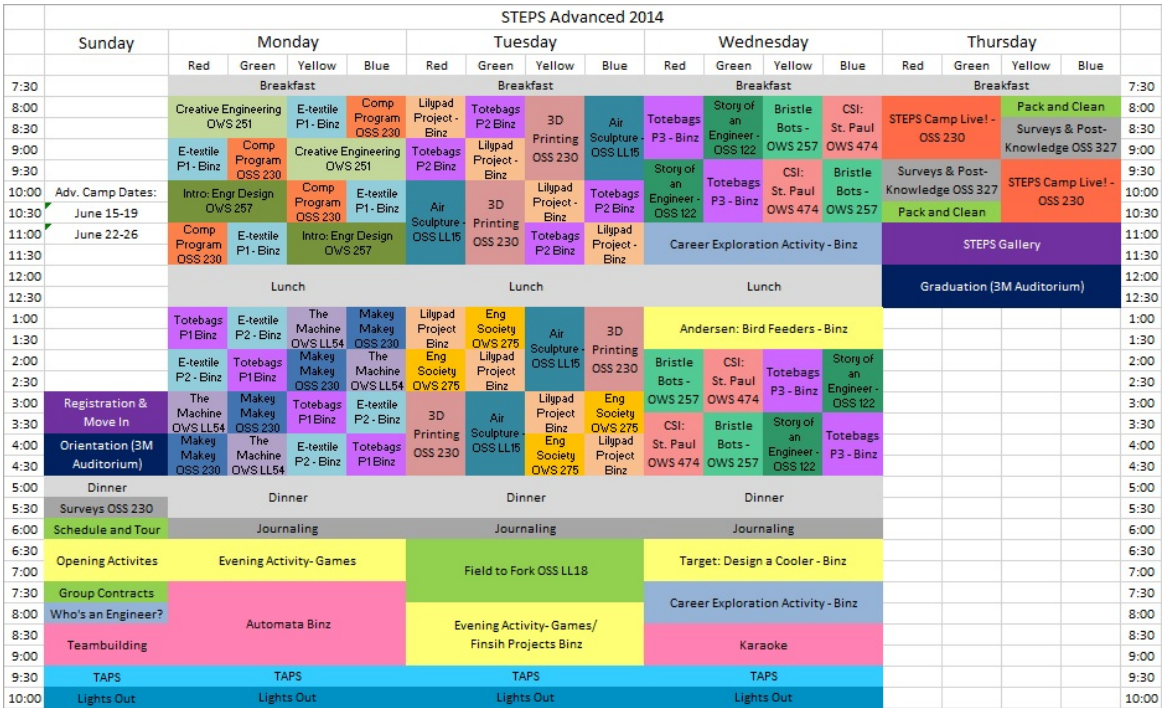
interacted with the piece different parts of the fabric made different sounds when you touched it. The girls were then asked to share what they knew about electricity and circuits and were given guiding questions (such as: “Are there different kinds of circuits? If so, how many and what are they called?”, “What is needed in order for a circuit to be complete?” and “What are good conductors?”). Once these questions were answered the girls were then introduced to series circuits which would be used for their first project. They were told that in a series circuit the electricity only has one path to follow and were shown pictures of series circuits. The first an introduction to schematic diagrams was included in the hopes that if the girls drew their own circuit diagrams for their bracelets they would have a better understanding of a series circuit, however this part took too much time and did not seem to help the girls and was taken out of the curriculum for subsequent weeks. The girls were then taught about unique components to e-textiles, such as conductivity of thread, and techniques that they would need to complete the project, such as testing the polarity of an LED.

With this information in mind the girls were then asked to create a bracelet that when it was put on, would light up one LED. The girls initially drew a schematic of their circuit and checked it with their instructors. Once their schematic was determined to be correct they were given supplies and tools to sew the circuit. This activity was given one hour and was to be completed every week of camp.

Camp Components

Seen below in Figures 1 and 2 are schedules for the campers for both Advanced and Basic camp respectively. While the girls spent most of their time in classes, they also spent time doing

engineering related activities, such as watching an engineering related movie or previewing work of undergraduate engineering students with quadrocopters. All meals were served in one of the university's cafeterias, and classes/workshops were taught in academic buildings where summer college classes were also being held.



STEPS Advanced 2014																	
	Sunday	Monday				Tuesday				Wednesday				Thursday			
		Red	Green	Yellow	Blue	Red	Green	Yellow	Blue	Red	Green	Yellow	Blue	Red	Green	Yellow	Blue
7:30		Breakfast				Breakfast				Breakfast				Breakfast			
8:00		Creative Engineering OWS 251		E-textile P1 - Binz	Comp Program OSS 230	Lilypad Project - Binz	Totebags P2 Binz	3D Printing OSS 230	Air Sculpture - OSS LL15	Totebags P3 - Binz	Story of an Engineer - OSS 122	Bristle Bots - OWS 257	CSI: St. Paul OWS 474	STEPS Camp Live! - OSS 230		Pack and Clean	
8:30																Surveys & Post-Knowledge OSS 327	
9:00		E-textile P1 - Binz	Comp Program OSS 230	Creative Engineering OWS 251		Totebags P2 Binz	Lilypad Project - Binz										
9:30										Story of an Engineer - OSS 122	Totebags P3 - Binz	CSI: St. Paul OWS 474	Bristle Bots - OWS 257	Surveys & Post-Knowledge OSS 327		STEPS Camp Live! - OSS 230	
10:00	Adv. Camp Dates:	Intro: Engr Design OWS 257		Comp Program OSS 230	E-textile P1 - Binz	Air Sculpture - OSS LL15	3D Printing OSS 230	Lilypad Project - Binz	Totebags P2 Binz								
10:30	June 15-19													Pack and Clean			
11:00	June 22-26	Comp Program OSS 230	E-textile P1 - Binz	Intro: Engr Design OWS 257				Totebags P2 Binz	Lilypad Project - Binz	Career Exploration Activity - Binz				STEPS Gallery			
11:30																	
12:00		Lunch				Lunch				Lunch				Graduation (3M Auditorium)			
12:30																	
1:00		Totebags P1 Binz	E-textile P2 - Binz	The Machine OWS LL54	Makey Makey OSS 230	Lilypad Project Binz	Eng Society OWS 275	Air Sculpture - OSS LL15	3D Printing OSS 230	Andersen: Bird Feeders - Binz							
1:30																	
2:00		E-textile P2 - Binz	Totebags P1 Binz	Makey Makey OSS 230	The Machine OWS LL54	Eng Society OWS 275	Lilypad Project Binz			Bristle Bots - OWS 257	CSI: St. Paul OWS 474	Totebags P3 - Binz	Story of an Engineer - OSS 122				
2:30																	
3:00	Registration & Move In	The Machine OWS LL54	Makey Makey OSS 230	Totebags P1 Binz	E-textile P2 - Binz	3D Printing OSS 230	Air Sculpture - OSS LL15	Lilypad Project Binz	Eng Society OWS 275								
3:30										CSI: St. Paul OWS 474	Bristle Bots - OWS 257	Story of an Engineer - OSS 122	Totebags P3 - Binz				
4:00	Orientation (3M Auditorium)	Makey Makey OSS 230	The Machine OWS LL54	E-textile P2 - Binz	Totebags P1 Binz			Eng Society OWS 275	Lilypad Project Binz								
4:30																	
5:00	Dinner	Dinner				Dinner				Dinner							
5:30	Surveys OSS 230																
6:00	Schedule and Tour	Journaling				Journaling				Journaling							
6:30	Opening Activites	Evening Activity- Games				Field to Fork OSS LL18				Target: Design a Cooler - Binz							
7:00																	
7:30	Group Contracts	Automata Binz								Career Exploration Activity - Binz							
8:00	Who's an Engineer?					Evening Activity- Games/ Finsih Projects Binz											
8:30	Teambuilding									Karaoke							
9:00																	
9:30	TAPS	TAPS				TAPS				TAPS							
10:00	Lights Out	Lights Out				Lights Out				Lights Out							

Figure 1: Advanced Camp Schedule

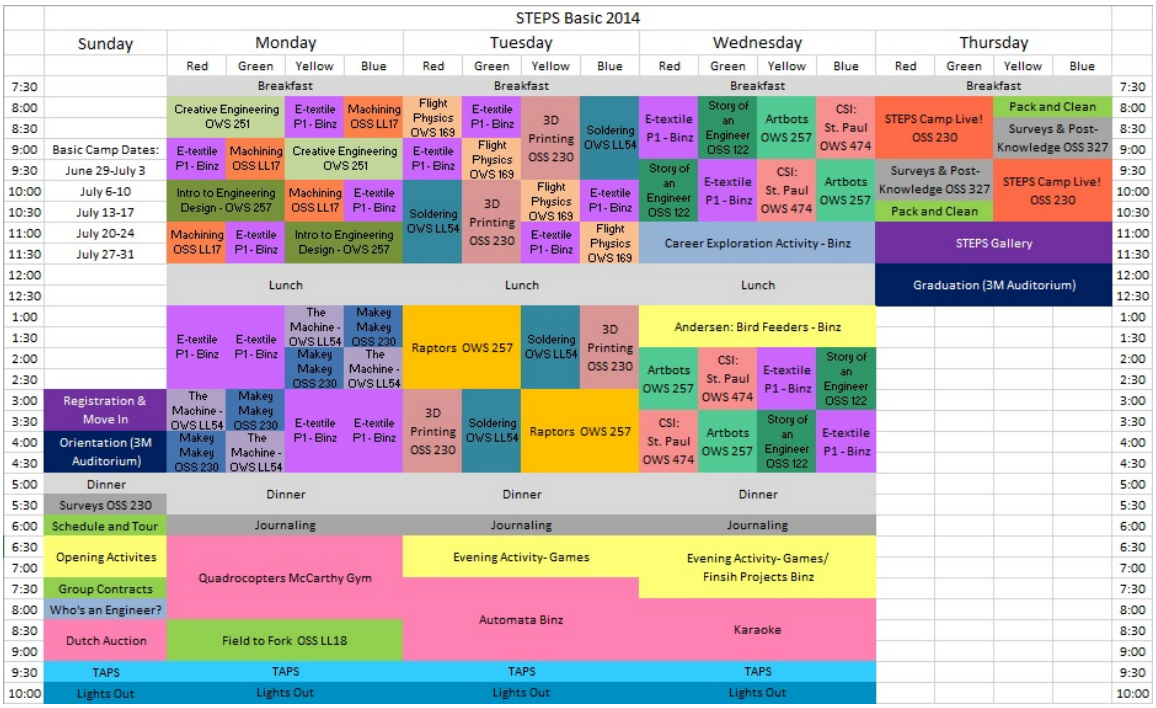


Figure 2: Basic Camp schedule

The STEPS camp at UST highlights interesting applications of STEM careers. The classes taught are intended to inspire and educate the girls attending the camp so they can leave with a better understanding of what a career in a STEM field entails, feeling empowered knowing that women can be successful in any career. Some classes, such as Machining and 3D Printing, taught the girls different manufacturing practices. These classes focused on a hands-on learning approach and the girls left with items they had created that could be used at home. Other classes, such as Raptors, were lecture-based, where the girls were able to see and learn about birds that had been brought into the camp for the day. These classes highlighted careers in the sciences at a camp whose primary focus was engineering. Still other classes, such as Story of an Engineer, asked the girls to practice writing creatively. Classes such as this one highlighted the need for an engineer to be well rounded and be able to communicate.

As in previous years there was one main project that was the focus of the camp and girls returned

to the project every day. In addition to the main project there were also smaller one to two hour long courses that highlighted other types of STEM careers or ways of thinking that are needed by successful engineers. As seen in the schedules, the Advanced girls worked on e-textiles making the bracelets for two hours of total class time, two hours designing and sewing tote bags, and one and a half hour to finish the tote bags by incorporating their e-textiles projects. The e-textiles projects were worked on during two hours of dedicated class time. The girls in Advanced camp spent a total of 8.5 hours of their 24 hours in classes focusing on e-textiles. In Basic camp the girls had five and a half hours of class time to complete their headbands in the e-textiles classes spread throughout the week.

Advanced Camp E-textiles Curriculum

The first two sessions (week 1 and week 2) of the 2014 UST STEPS camp season were Advanced Camp. On the second day of camp the girls were introduced to parallel circuits and microprocessors. These groups used the Lily-Twinkle, a pre-programmed microprocessor, to connect three or four LEDs as part of a light-up patch that would then be sewn onto a bag. The girls would then take their bracelet and bag home.

The original plan was to use this same project for both sessions of Advanced STEPS, however the bag project took longer than planned and some girls left camp with unfinished projects. Additionally, some participants voiced displeasure over the focus on sewing and feedback seemed to show that the girls did not see the relevancy of e-textiles to wearable technology. For session two a headband, which required less sewing than a bag, was introduced to replace both the bracelet and the bag projects. Additionally, a half hour discussion on e-textiles was added

into the teaching time, which allowed the girls to realize the role such technologies play in the design of space suits and wearable such as the Fitbit. Significantly more girls completed the headband project than did the bag project the prior week.

Basic Camp E-Textiles Curriculum

Using the lessons learned from the two sessions of Advanced Camp, it was decided that the headbands (including the hand sewing of parallel LED circuits) would be used for the Basic camp. During the first week-long Basic camp session it was determined that the younger girls attending Basic Camp had a more difficult time understanding the parallel and series circuits, and the nature of a diode. Thus, an interactive circuit discussion was also incorporated into the class time for future weeks, with the hopes that after seeing the tangible circuit the girls would have an easier time designing their headband circuit. During this week additional instruction was given in the area of hand sewing the circuits, which included demonstrations on tying knots, the proper spacing for stitches, and tacking LEDs and battery holders to the fabric. The supplemental instruction added gave the girls less time to work on their projects, but the projects were more effectively completed with this extra instruction time.

Figures 3 and 4: Campers working on their e-textiles projects.

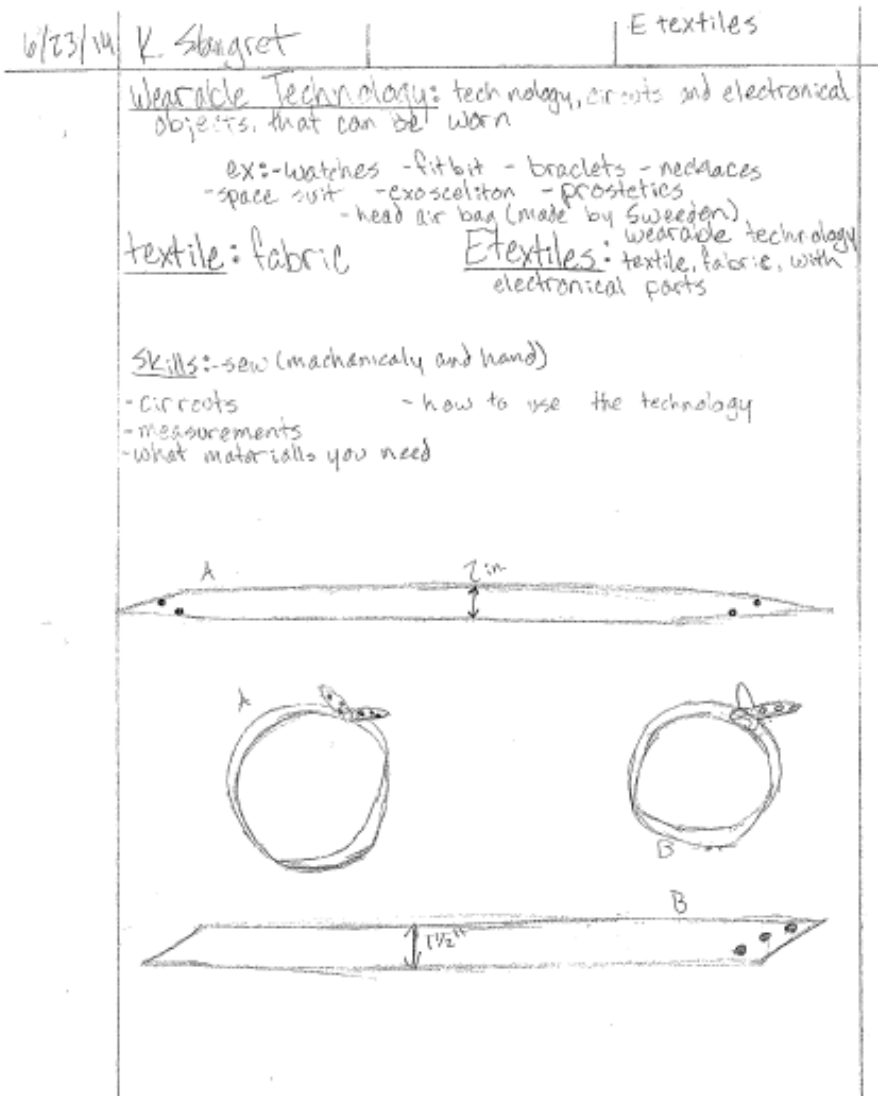


Figure 5: A camper's notebook showing her plans for her e-textile bracelet.

In moving away from the bag project to the headband project, the chance for a discussion of pattern geometry was sacrificed. For the second week of Basic camp a compromise between the bag project and the headband project was reached in having the girls create light-up pencil pouches. Pencil pouches combined the geometric thinking required for the bags with the scale of the headbands. The pencil pouches saved time by removing the handles that had been the step that most girls had not had a chance to complete in the first week. The girls would then sew

patches onto the pouches that had small parallel circuits on them. Unfortunately these projects were not all completed in time and it was decided that the headband project would be used for the remaining Basic camp sessions.

Evaluation

Several data sources were collected from Advanced and Basic campers in summer 2014. Both qualitative and quantitative data sources were used to better understand the influences of the camp on participants. We discuss the data sources and analyses in the following section.

Advanced STEPS Assessment

For this part of the evaluation, data was collected from 40 girls who participated the first week of the STEPS camp in the summer of 2014. Several new activities such as E-textile and career exploration were included in STEPS 2014. Girls were also asked to keep an engineering notebook to record their learning as they complete activities in the camp.

The evaluators observed the girls while working on e-textiles. The majority of the girls were highly engaged in the activity. The designs were very creative as well. The survey results showed that while 90% of the girls indicated that they enjoyed the activity and would definitely do it again, several girls voiced unhappiness with the project choice. The girls gave the following reasons:

> *"I didn't like sewing all that much I felt like I wasn't really learning anything all that useful that I couldn't learn somewhere else. I really wanted to try to make things like not with sewing though I felt like we used to much time on it and I still never learned what exactly a e-textile is and neither did the girls in my group doing all the sewing and it didn't feel like we did as much engineering kind of stuff."*

"I did not like the lily pads or the e textiles. The teacher was very good I just think that when you think of science you don't think of sewing. I mean yeah the circuits but sewing is not a 14 year olds first choice. I loved the teacher she made it fun but also I am not the best sewer and I don't care for sewing so it was hard to like and I couldn't get the lily pad to work so that was frustrating."

Basic STEPS Assessment

Draw an Engineer

Assessment of the 2014 Basic STEPS Camp included participant pre and post surveys, participant engineering notebooks, and analysis of daily reflections. Participant engagement with the e-textiles showed the most electrifying measurements. Girls were asked before and after their STEPS experience to complete an activity called "Draw an Engineer."[4] In this activity the girls first described what engineering is and then what engineers do. They were then asked to draw an engineer. The drawing in particular is meant to capture stereotypes that students may have towards engineering[4]. Girls at STEPS were given this activity before and after camp to evaluate how their perception of what engineers do changed. Due to time constraints, some girls only completed a pre- or post- survey, thus it should be noted that the pre- and post- results, while all from Basic camp participants, consisted of different girls.

	Pre (%)	Post (%)	CHANGE
Make/Build	42.93	30.63	-12.30
Fixes	10.87	8.11	-2.76
Improves	16.85	18.92	2.07
Creates	27.17	30.63	3.46
Designs	13.04	18.02	4.97
Invents	5.43	5.41	-0.03
Studies	7.61	3.60	-4.01
Help People	22.28	38.74	16.46
Problem Solves	17.39	30.63	13.24
I don't know	1.63	0.00	-1.63
Works with/on Computers	1.09	1.80	0.71
Total Number of Tests Used	184	111	

Table 1: Analysis of Basic STEPS' camp responses to "What does an engineer do?" prompt.

The most significant change in the written responses was that a significantly higher percentage of the post-responses mentioned helping people and/or problem solving. There was also a decrease in the percentage of responses mentioning making or building.

In the "Draw an Engineer" picture responses post- surveys had slightly more women or indeterminate gender drawings and the engineers included a wider range of activities beyond fixing things, driving trains, and computers.

	Pre (%)	Post (%)	CHANGE
Gender undetermined	63.10%	59.83%	-3.27%
Female	21.39%	27.35%	5.96%
Male	8.56%	5.13%	-3.43%
Both (more than one person drawn)	3.21%	5.98%	2.77%
No Person drawn	3.74%	1.71%	-2.03%
Total	187	117	

Table 2: Analysis of drawn gender for the engineers in the Basic STEPS' camp responses to the prompt "Draw an engineer."

Daily Reflections

Another form of assessment of the camp used was daily reflections for the girls. Throughout camp, campers were asked to fill out a reflection on their day to get a more focused view on how effective the individual days were. There were two prompts on the reflections: "What I learned about engineering and design process" and "What I want to know." These reflections were then read through and below are a few salient responses.

Selected "What I learned about engineering and engineering design process" responses:

"There are lots of different ways to be an engineer (sewing, computer, metal)."

Responses such as this one indicate that one of the goals of the 2014 STEPS camp - that the girls learn about the diversity of engineering fields - was successful.

"I learned about short circuits and how to fix them in my sewing project."

One of our goals as instructors was that the girls would learn about important electrical engineering concepts. Short circuits were a topic we emphasized, as they are a key concept in any electrical engineering application. Additionally, a goal of the e-textile curriculum was that the girls would learn about the iterative problem solving nature of engineering. Through learning how to fix their projects themselves, we hoped to empower the girls in future problem solving endeavors.

"I learned that the engineering design process can be benefiting but frustrating especially in E-textiles for me."

One concept that was wrapped into any course that it worked with was that of the engineering design process. There were even several posters of The Works museum's version of the engineering design process in many of the classrooms. Here we see that the class worked to incorporate not only varying topics of STEM and engineering but also the overarching hope that the girls would take away habits of mind that lead to successful engineers.

Selected "What I want to know [about engineering and engineering design process]" responses:

"I want to know why my LED bracelet didn't light up. I sewed everything on correctly. I think it might be the way the battery and bulb is faced."

This comment shows some of the positive and negatives attributes of the STEPS camp. There were times when the girls showed great interest in problem solving and had theories of why their circuits did not work. However, the amount of time needed for the projects was longer than originally anticipated (in the early sessions), so girls occasionally went home with incomplete projects or the coordinators had to troubleshoot the projects for the girls. When the instructors did the troubleshooting for the girls, the camp participants missed a critical component of the design process.

"Is there such a thing as too many lights on a circuit?"

While the project encouraged some girls to explore more fully the ideas discussed in the e-textiles classes, some girls were discouraged from the topics, like this girl who asked:

"If you can't sew can I still get a good job as an engineer?"

This questioning shows that maybe too much emphasis was put on the main project and that some of the girls were having difficulties in connecting all of the things that they learned to all being under engineering.

While some girls noted gained knowledge through either the teaching of the class or through correcting their own projects, other girls developed questions from the class and were inspired to reach a better understanding of components of the project, seen in their responses to the second prompt of "What I want to know." Many of these girls were intrigued by these projects which led them to ask more questions to better understand the activity. However, some of the girls questions showed they did not understand that while sewing can be a part of engineering, just like welding or 3D printing, it is not something all engineers have to do.

Post-departure online survey

Further evaluation of the camp occurred through an online survey the girls were asked to take when they returned home from camp. The survey included a variety of questions about engineering, overall STEPS camp experience, and questions about the classes that they took. One girl on her post survey said that one of the first three words that came to her mind when thinking of "Engineering" was e-textiles, another included sewing. When asked, "What benefits did you gain from being involved in the STEPS program?" one girl said, "*I learned how to design new things like the wearable electronic headbands and artbots, and now I have some ideas I might want to try out at home."*

While many girls said that e-textiles was one of the things they liked best about the STEPS program, a few girls mentioned they liked the e-textiles class the least. Some such comments were: *"Not having a second choice, like forced to make the headband, even if we didn't want to." "Sewing our head bands because its confusing."* Another relevant comment: *"The LilyPads were hard and so were the etextiles and they weren't really cool or they didn't have anything to do with engineering."* This comment also once again highlights that the girls were not given sufficient context to what e-textiles were, and thus did not understand their relevance in engineering.

Since some participants did not enjoy or understand e-textiles inclusion in the camp, a better way to fully engage all of the girls in the e-textiles discussion is necessary. The primary focus of e-textiles discussions was on other wearable technologies, many of which did not seem to include sewing. This could have been a reason why the girls felt there was a lacking connection between our e-textiles project and science and engineering.

Conclusion

While the overall feedback and evaluation of e-textiles into the 2014 STEPS summer camp showed that many of the initial goals for the curriculum change were met, the implementation was not without challenges and concerns. As stated earlier, three goals for the new curriculum were:

1. That the main project be functional once the girls brought it home
2. That the project allow for unique solutions and personalization

3. That the project allow for discussion of the ways engineering could make a positive impact on people's lives

Goal 1 was met for many, but not all of the campers. In future iterations, a stronger contingency plan must be developed for assisting campers whose projects are not working. The variety of designs and patterns created by the campers satisfied us that goal 2 was met. It is a bit harder to tell whether the e-textiles project helped address goal 3. While the "What does an engineer do" question results from Basic STEPS campers showed a substantial increase in the percentage of respondent's mentioning that engineers help people, the written comments about the camp showed some displeasure regarding the choice of sewing as a project, and confusion as to how this project relates to wearables and engineering. Based on participant feedback, a modified curriculum is being written in hopes of more successfully meeting these goals in future versions of the camp.

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