Filling the Pipeline by Exciting Middle School Girls with Creative Projects

Megan Charlotte Karbowski, Loyola Marymount University

Megan Karbowski recently received a B.S. degree in computer science from Loyola Marymount University where she participated in a university-funded summer research project to design hands-on activities for middle school girls. She is currently a Graduate Web Developer for ARUP.

Ms. Mackenzie Tjogas, Loyola Marymount University

Mackenzie Tjogas is a Fullstack Software Engineer for Honey. She recently received a B.S. degree in Computer Science from Loyola Marymount University where she participated in a university-funded summer research project to design hands-on activities for middle school girls. Mackenzie was a part of Belles Service Organization throughout her time in college and worked with young girls in the LA community on a weekly basis through this organization. She incorporated STEM and specifically computer science into this work as often as she could.

Miss Carleen Petrosian

Carleen Petrosian recently received a Bachelor's degree in Computer Science and a minor in Business Administration from Loyola Marymount University. During that time, she was a Software Engineering intern for American Bars and she participated in a university-funded summer research project to design hands-on activities for middle school girls. Her current research interests include visualization, human-computer interaction, and K-12 STEM outreach.

Dr. Barbara E. Marino, Loyola Marymount University

Dr. Barbara E. Marino is an Associate Professor in the Department of Electrical Engineering and Computer Science at Loyola Marymount University. She also serves as the Undergraduate Director for the Electrical Engineering Program at LMU. Her current research interests include engineering design and K-12 STEM outreach. Dr. Marino received the B.S.E.E. degree in 1989 from Marquette University and the M.S. and Ph.D. degrees in electrical engineering from the University of Notre Dame in 1993 and 1996, respectively. In addition to her current positions she has held various positions at the Naval Research Laboratory and the Jet Propulsion Laboratory.

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Introduction:

Despite some progress, the gender imbalance in electrical engineering and computer science in higher education and in industry has persisted. ASEE reported that in 2016, women made up just over 20 percent of students pursuing Bachelor's degrees in engineering, with an even smaller percentage of women students pursuing degrees in electrical engineering (12.7%) and computer science (12.3%) [1]. To address this imbalance, educators and innovators have developed programs designed to invite, excite, and welcome girls to these fields where they are underrepresented. Alexa Café by iD Tech Camps [2] and Berkeley's Girls in Engineering [3] are two such examples, but clearly more programs are needed.

In the summer of 2016 three female undergraduate students, serving as mentors, participated in a university-funded summer research project to design a one-day camp experience to introduce middle school girls to the fields of computer science and electrical engineering through hands-on activities. Five activities were identified to introduce the middle school girls to a variety of basic hardware and software concepts. In addition, the activities were selected based on the level of skill required to complete and the perceived fun factor. The mentors prepared handouts for each activity, created pre and post surveys, purchased supplies and organized the laboratory spaces as part of the project.

Figure 1: Group shot of mentors (kneeling) with participants.

This one-day camp was offered in late June and drew eight girls of a variety of racial and ethnic backgrounds from a Los Angeles Unified School District middle school. A picture of the girls with the undergraduate mentors and the faculty mentor is shown in Figure 1. Throughout the day, the labs were filled with excited chatter and laughter as the mentors led the girls through the activities. The post-camp surveys echoed what we already knew to be a successful day. The day even extended an hour past the scheduled end because the girls wanted to continue to work on the final activity. This paper presents the hands-on activities for replication and adaptation by others and reviews the survey feedback from both middle school girls and the college mentors.

Logistics:

Research on creating an environment for underrepresented students indicates that these students thrive and gain confidence when working in groups where they are the majority [4][5]. To ensure that this was the case, only girls were invited to participate in the day of activities. Research also stresses the importance of mentors [6][7][8], so the groups [9] were kept small and the ratio of mentors to student participants was kept high. With the additional presence of a faculty mentor, the ratio of student participant to mentor was 2-1, providing many wonderful opportunities for the girls to make connections.

It was also important that the activities take place on the university campus. Research indicates that students are more likely to succeed in college if the environment is comfortable and familiar to them [10]. One of the goals of this project was to introduce the girls to various laboratories in a fun and inviting way so when deciding on their future they have positive experience in the spaces used for engineering and computer science.

Schedule:

The middle school girls arrived at 9am on campus, a site chosen to expose the girls to a higher learning STEM environment. During the first 45 minutes the mentors introduced themselves, assigned small groups and went over the schedule for the day shown in Table 1. The introductions offered an opportunity for the mentors to offer their experiences as models and as a forum of sharing to make them more approachable to the participants. The girls were also asked to complete the pre-survey, shown at the end of the paper in Figure 13.

The day combined large and small group activities, although even a large group of 8 still offered plenty of attention for each student. The students participated as a whole in two of the hands-on activities (Coding in Lightbot and Designing an Electronic Greeting Card) and in smaller groups for the remaining three activities. The activities were all essentially individual, except for Building with littleBits.

The location of the activities was chosen intentionally to introduce the girls to various engineering and computer science spaces. The Maker's Space is a comfortable space stocked with processor boards, motors, lights, colorful breadboards, soldering stations and various craft supplies. It is designed to offer a comfortable environment that also inspires experimentation and exploration. There are reconfigurable tables and chairs, a rug for comfortably working on the floor and even a couch. The other two spaces, the electronics laboratory and the computer laboratory, are traditional spaces not unlike those found in most electrical engineering programs. All were chosen to highlight the facilities and to expose the girls to different learning environments.

Time	Location	Activity
9:00am – 9:45am	Maker's Space	Introductions, Overview, Pre-surveys
9:45am – 10:30am	Electronics Laboratory	Coding in Lightbot
10:30am – 11:15am	Computer Laboratory Electronics Laboratory Maker's Space	Creating an Animation in Alice Animating LED Lights with an Arduino Building with littleBits
11:15am – 12:00pm	Computer Laboratory Electronics Laboratory Maker's Space	Creating an Animation in Alice Animating LED Lights with an Arduino Building with littleBits
12:00pm – 1:00pm	Engineering Quad	Lunch
1:00pm – 1:45pm	Computer Laboratory Electronics Laboratory Maker's Space	Creating an Animation in Alice Animating LED Lights with an Arduino Building with littleBits
1:45pm – 2:45pm	Maker's Space	Designing an Electronic Greeting Card
2:45pm – 3:00pm	Maker's Space	Post-surveys, Goodbyes

Table 1: Detailed schedule of activities

Coding in Lightbot:

Lightbot is an app and web-based video game [11]. It allows for a fun and easy way to learn programming concepts such as if-then statements, functions, and loops, without actually typing in any code. Users can learn how to think like a programmer by finding patterns, forming solutions, and debugging when necessary.

The objective of the application is to get the bot to visit each of the blue spots (Figure 2) and to light them up, only using the space provided for the solution. Instead of using words, like typical programming, the application uses symbols to make it easier for the user to visualize and develop their solutions to the puzzles. (Figure 3 shows one of the girls solving a challenge.)

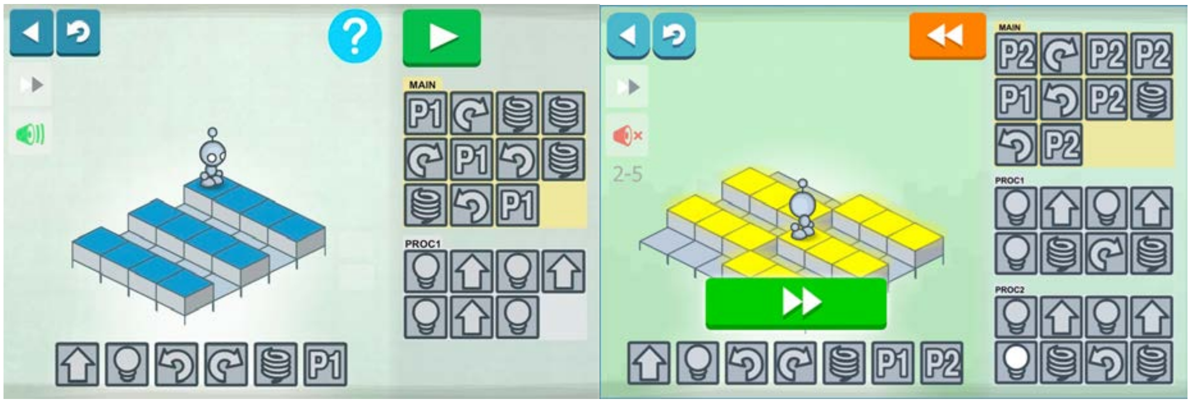


Figure 2: Screenshots from Lightbot Activity [12].

This activity fostered collaboration and peer education. As the girls finished the activity, they naturally migrated over to others who were still working. They explained how they approached the problem and ended at their solution. This positive and playful environment proved to be a successful context for students to interact with each other to learn foundational coding concepts. They were able to experience some of these concepts in a fun and non-intimidating fashion, which kept them more engaged in the activity.

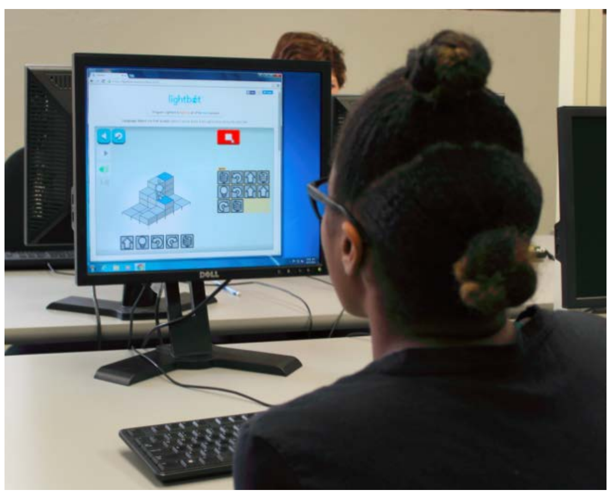


Figure 3: One of the participants engaged in Lightbot activity.

Creating an Animation in Alice:

Alice [13], named for Alice and Wonderland, is a tool that helps make computer programming simple and fun. Alice allows participants to create an animation by using object-oriented programing techniques. This teaches the very basic and foundational concepts of programming, and it does so by letting them create animated movies, games, scenes, etc.
By merely dragging and dropping the given tiles (people, animals, cars, etc.) participants create a program. The instructions given are made to correspond to one of the languages offered, all of which are object-oriented programming languages like Java, C++, and C#. Participants get

immediate feedback from their work as they see their animation come to life. This fosters the understanding of how programming statements and the objects they control are connected. Figure 4 shows a screenshot of the Alice activity.

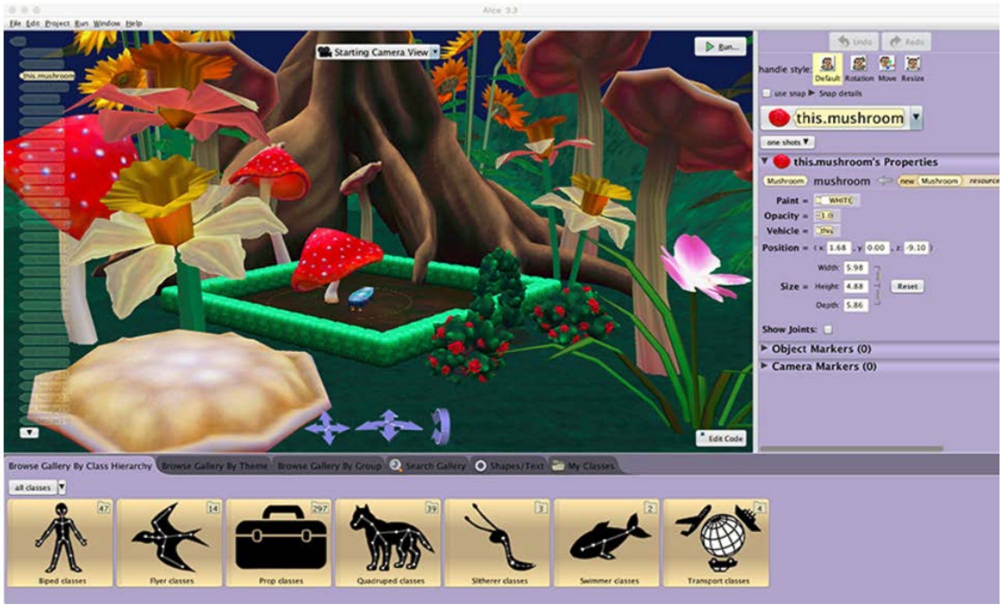


Figure 4: Screenshot of Alice Activity [14].

The girls each created their own animation that required at least two classes (people, animals, etc.). They took a little bit to familiarize themselves with the Alice environment and play around with the different tools offered. As they grew more comfortable they were able to utilize the functions given to make their animations come to life. The girls completed their animations and had the opportunity to show each other what they had created. After seeing what their friends had created all of the girls were inspired and wanted to add more to their own animations. Figure 5 shows one of the girls getting feedback on her Alice program from two of the mentors.

Figure 5: Two mentors assisting one of the participants in Alice activity.

Animating LED Lights with an Arduino:

SunFounder Uno boards were used for an activity similar to one developed by SunFounder [15]. Each girl was given a SunFounder Uno board on which an Arduino Uno microcontroller and a small breadboard were mounted. The girls learned how to assemble a small circuit with eight LEDs and eight 220Ω current-limiting resistors on the breadboard and interface it with the microcontroller. The programming environment was launched on a PC, and an example program was provided that consecutively lit one LED at a time with a pause between illuminations. Once all the LEDs were illuminated, the program would consecutively extinguish each LED in the reverse order. Figure 6 shows two pictures taken during the activity.

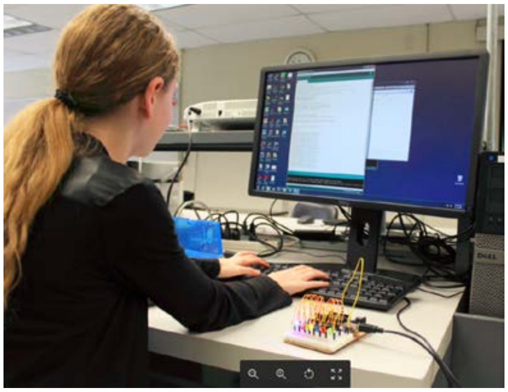
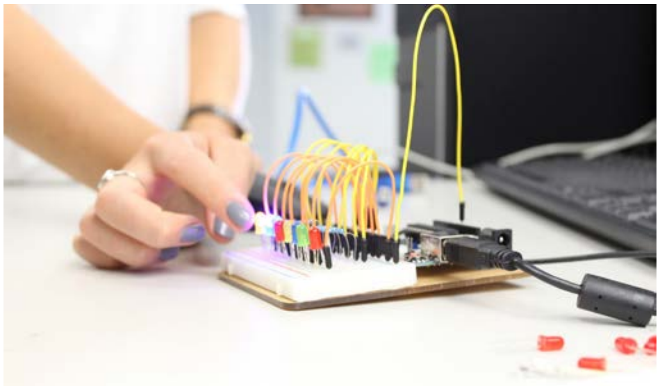



Figure 6: One of the participants engaged in Arduino LED lights activity.

Lacking any experience with this type of hardware, the girls were initially nervous. However, since this was a small group activity, the mentor was able to encourage the girls and immediately answer questions or address any concerns. This activity was a wonderful example of how hardware and software can work together in a design, combining electrical engineering and coding concepts in creative problem solving.

Once the initial challenge was completed, the girls were encouraged to alter the program to change the illumination pattern of the LEDs. This could be done by changing the pattern of LEDs illuminated and/or changing the delay between actions. Unfortunately the tight schedule did not provide sufficient time for the girls to explore these additional challenges.

Building with littleBits:

littleBits is a company that makes modular electronic and mechanical components that connect together using polarized magnets creating a wonderful platform for design. In addition to selling the individual bits, the company has also created kits containing an assortment of pre-selected bits packaged with a booklet describing several creations that can be created with the modular components.

The Synth, Gizmos & Gadgets and Steam Student kits were provided to the girls for one of the activities of the day. No directions were given and no challenges were made. This was intentional and done so the mentors could observe the girls as they participated.

With no clear objective or experience with the kits, the girls spent time exploring the different bits. Although the other activities throughout the day were individual, the girls still found ways to work together, sharing ideas and giving help when needed. Consequently, it was no surprise then that the girls chose to work as a team on this open activity. However, the response from the students on this activity was mixed. One of the groups was fully engaged and excitedly sharing ideas (this group is shown in Figure 7) while the other two groups were more quiet and hesitant. The lower level of engagement in this activity by some was likely due to the open-ended nature of the experience. In all of the previous activities of the day the girls were given an introductory task to accomplish prior to a challenge activity. With this activity, no such directions were given.

The littleBits activity could be improved by including more assistance from the mentors. The mentors could offer a few suggestions to the groups that needed a bit more encouragement. Nonetheless, the goal of this activity to help the girls develop their confidence in independent exploration with hardware was achieved.

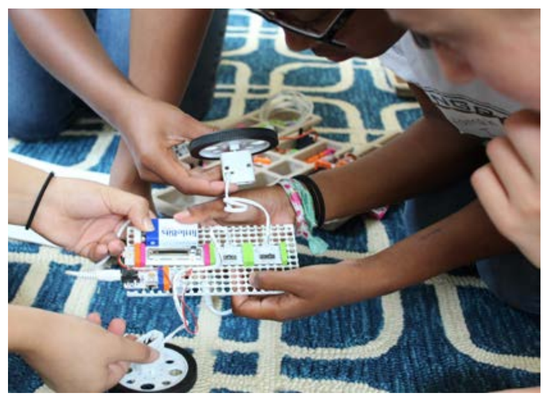



Figure 7: Participants engaged in littleBits activity

Designing an Electronic Greeting Card:

During the final activity of the day, the group returned to the Maker's Space. The girls learned about batteries, polarity, conductive materials, LEDs and DC motors. They were also taught how to solder. They were then challenged to use their own creativity to design an electronic greeting card.

The activity started with a long brainstorming session. The girls were very excited, but also a bit intimidated by this project, so it took each a while to settle on the perfect idea for her card. They selected colored paper, some cutting it into shapes, and sketched out the placement of their electronics. Conductive tape, pens with conductive ink, wires, 3V coin batteries, batteries cases, motors, Chibitronics circuit stickers and various size, shape and colored LEDs were provided. There was also plenty of colored pens, scissors, glue and tape.

Once the bulk of the design was complete and the conductive material laid out on the paper, the girls worked one on one with a mentor to solder their LEDs to their card. Figure 8 shows the girls working with their mentors on the activity.

Figure 8: Participants engaged in paper circuit activity.

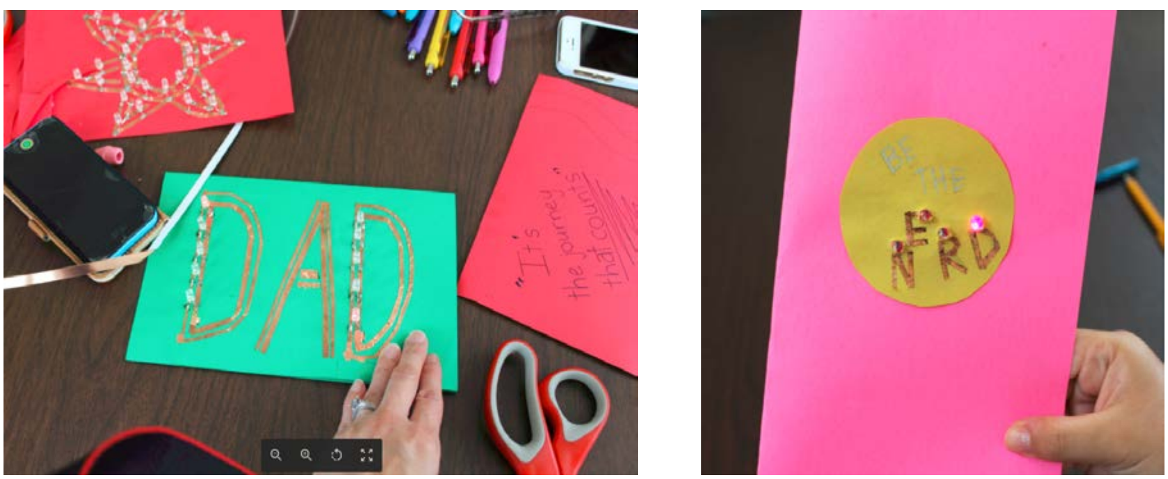


Figure 9: A few examples of paper circuit designs

As this was late June, many of the girls decided to make Father's Day cards. This particular group of girls was extremely detail-oriented, wanting to create the perfect card, so the complete activity took much longer than expected. After the first hour the girls begged their parents to let them stay so they could finish their creations. They spent nearly two hours on this activity. And since it involved their own creativity, they were most proud of their work. Figure 9 shows several of the final products.

Assessment:

Pre-surveys were administered to the participants at the beginning of the day. The survey is shown in Figure 13 at the end of the paper. Two questions yielded particularly interesting responses.

When asked if the participant had ever been embarrassed to ask a question in class, every participant answered yes [Figure 10a]. When prompted to explain, one student wrote that she was worried she would be thought of as less. Another student wrote that she didn't want to seem stupid. These responses confirm other research that shows girls lack confidence in the areas of math and science, even though they often outperform boys [16].

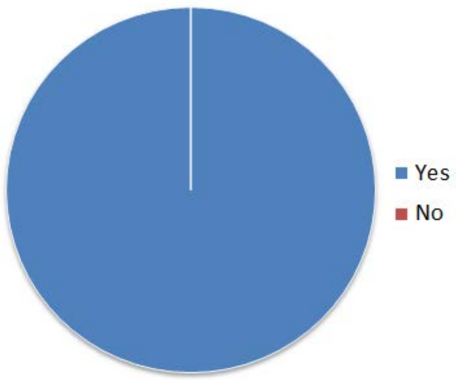
Another question from the pre-survey that yielded interesting responses asked the girls to rate their interest in math and/or technology. These responses are shown in Figure 10b, where a 1 indicates no interest and a 7 indicates that she is *SUPER* interested. Because this is a self-selected group, opting to participate in this day of technology, none of the girls responded with a 1 or 2. Both girls who responded with a 7 also indicated that they have previously participated in a coding or software class.

Post-surveys were administered to the participants at the end of the day. The survey is shown in Figure 14 at the end of the paper. Three questions yielded particularly interesting responses.

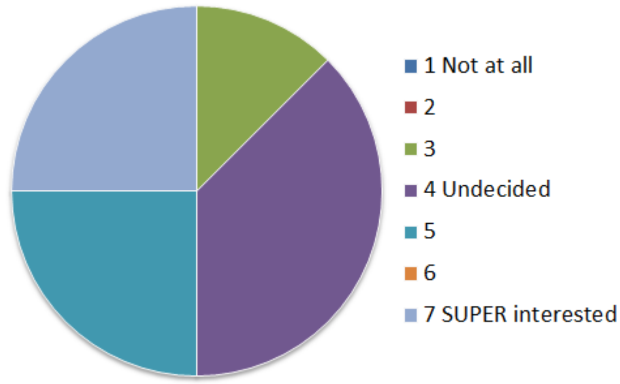
When asked what interested them the most about technology, Figure 11a, five of the eight girls indicated that they were most interested in coding. Seven of the eight girls were interested in learning more about programming and animation when asked what topic they would like to learn more about. This directly correlates with the types of activities the girls participated in throughout the day.

Three out of the eight girls would consider going into a math or technology-related major in college; on a scale of 1-7, one of the girls chose a 7, another a 6, and the last a 5.
In addition to the data collected using the surveys, the observations of the mentors provided valuable insight. The mentors observed that the girls were more engaged in the activities for which there was a specific initial task to be accomplished, like with the animated LED lights, as opposed to the open-ended activities, like with the littleBits components. Having an initial task to accomplish gave the girls direction and confidence with the hardware or software before tackling additional more challenging tasks. The mentors also observed that the girls were most excited

about the paper circuits activity. The mentors attributed this to the creative aspect of the activity. The girls were very proud of their creations and no two looked alike.

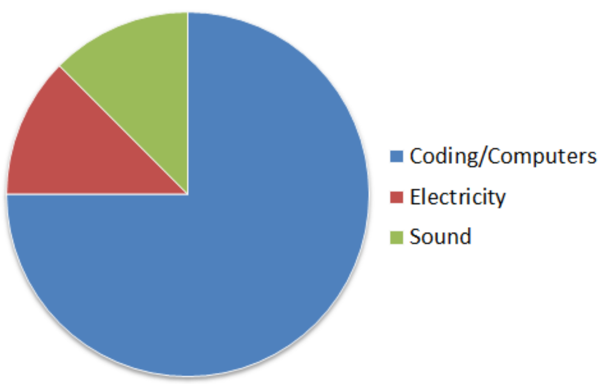


a) Have you ever been embarrassed to ask a question in class?

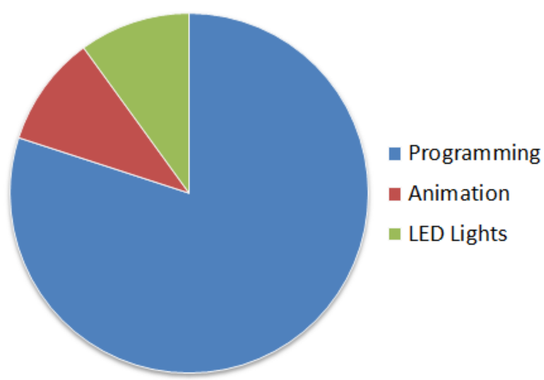


b) Are you interested in math and/or technology

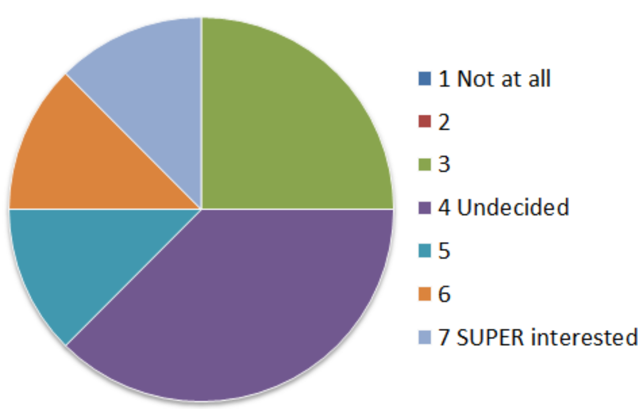
Figure 10: Pre-survey results.



a) What interests you most about technology?



b) What would you like to learn more about in terms of engineering/computer science?



c) Would you consider going into a math or technology-related major in college?

Figure 11: Post-survey results.

Mentor Feedback:

Comments from the mentors suggest secondary beneficiaries of these workshops, the mentors. The feedback from the mentors below indicates the positive effects of this workshop on their development as future leaders, while reinforcing the need for such workshops.

Mentor 1: Participating in this research project was motivating, surprising, and helped to ignite a passion within me to continue doing this kind of work. Before we began researching I knew about the gender gap in computer science and had witnessed it first hand as a female computer science major, but I wasn't well read on the specific numbers and what was being done to change it.

Learning about how powerful mentorship can be for young women influenced our project and has stayed with me since. As a member of a service organization, I have the privilege of going to service every week for almost two years, often working with the children. After this research project I made it my mission to talk to all of the young women I worked with about computer science and engineering. All of the girls were in either elementary or middle school, which were the age groups we had researched the most. It was incredible to see there excitement grow about these two disciplines after I continued to talk about them week after week. I will continue to do this in any environment I can in the effort to expose as many young women as possible to their potential.

Mentor 2: When I was in middle school, I wasn't introduced to or encouraged to consider pursuing a career in computer science or engineering. When I began to apply for colleges, I began asking around and my Calculus professor told me Computer Science would be a good fit for me. I didn't know anything about coding and wasn't familiar with any of the concepts, but I took the risk and applied anyways as a Computer Science major. When I started my first week of classes, I felt intimidated by my peers; the classes were almost all males, and I didn't have any experience. I thought I was already at a disadvantage and would fall behind on all of the work.

If I had been exposed to computer science and engineering at a younger age, it would have been less of a risk to apply for that major. It also would have increased my interest level and engagement in the subject, causing me to become more confident in my abilities to learn new concepts. Stereotypes around these fields deter women from pursuing them in their college careers. I think it was important for these girls to be exposed to computer science and engineering at a young age so they can be more confident with their abilities. They can learn some of the difficult concepts in a fun and non-intimidating fashion. They, too, can pursue a career in these fields, much like their male counterparts.

Mentor 3: My experience during and after the research project was very positive. Like Mentor 1, I was also aware of the gender gap in engineering fields, but was not familiar with what was being done to close this gap. After extensive research and involvement with mentoring first hand, I realized how something that seems so small can make a big difference. It was incredible to be able to mentor a group of girls and witness how far simple encouragement can go. I am inspired to help other women succeed, not only in engineering related fields, but in their professional lives as well. The gender gap affects more than just what jobs women pursue, but also how they act within those positions. It not only impacts those who are minorities in their major, but also those who are a minority in their professional career. Research as well as mentoring programs like this need to happen throughout the future to begin the process of reducing the gap.

That said, this research project resonated well with my personal experience in the past with female mentorship. Reflecting on how I got to where I am today, I owe much of my success to the female mentors that have influenced me so positively throughout my high school and college years.

Recommendations for Future Camps:

For many of the activities there was a scripted part and an additional challenge planned, but time prohibited most of the girls from thoroughly exploring the additional challenges. In the future more time will be allocated to each activity. According to these results, 75-90 minutes per activity would be sufficient. This will of course limit the number of activities, but the additional time spent to master the nuances of each activity is worth the limited exposure.

Extending the coding activities: The surveys revealed that the girls were very interested in coding and wanted to know more about coding and software. Although Lightbot and Alice teach fundamental computer programming techniques, the girl's interest indicates that the activities can include more programming. This can be done by extending the SunFounder activity or by adding a second activity that provided only a small amount of example code.

Extending the hardware activities: The girls particularly enjoyed the electronic greeting card because of the skills learned and the creative aspect of the activity. After the camp, we designed another activity around building a nightlight that could be used in the future that provides many of the same benefits the girls so enjoyed. For this activity, an astable oscillator circuit using a 555 timer IC can be used to create a nightlight that turns on and off in some predetermined pattern. After a brief explanation of the oscillator circuit, each girl can be challenged to determine the value for the resistor and capacitor that will produce the output desired for their nightlight.

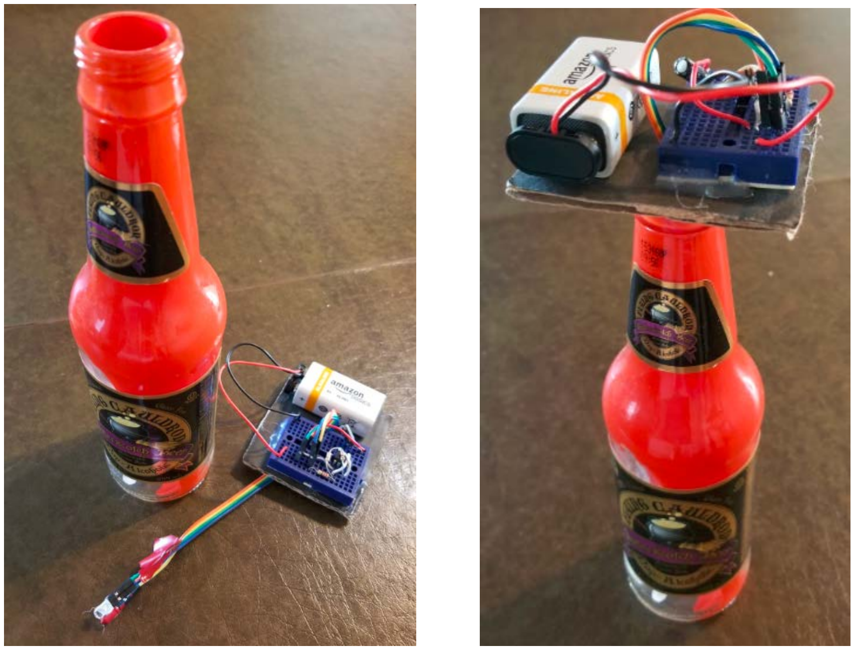


Figure 12: 555 Timer Night Light

During a test of the activity, a 555 timer circuit was assembled on a 170-point mini breadboard. The breadboard and a 9V battery were mounted on a piece of stiff cardboard, and long leads connected two LEDs to the output of the oscillator. The LEDs were dropped into a clean, glass bottle and the cardboard secured to the top of the bottle using hot glue. The finished product can be seen in Figure 12.

Widen the scope of the investigation: Finally, based on the feedback of the mentors, it would be useful to view the workshop as an educational experience for them as well. Pre and post surveys for them would also help measure the impact of the experience while helping to frame the activity as mutually beneficial, as a communal learning opportunity and a growth experience for all involved.

Conclusion:

The surveys showed that all participants had, at some point, been too embarrassed to ask a question in class. The fear of seeming less intelligent than their peers can cause young women to avoid asking questions. This anxiety is discouraging and may deter them from taking full advantage of their education. The surveys also showed that our day of activities did increase interest: six out of the eight girls reported they loved the activities and would do them again. This research indicates, at least with respect to the participants, that the gender discrepancy in engineering and computer science does not come from a lack of interest. Involvement in these fields is increased when young women are taught in a collaborative environment that is relaxed and encouraging, supervised by invested mentors, who are also growing through their involvement.

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Assessment/Measure Questions for Middle School Girls:
Pre Experiment:

1.) What grade are you in?

2.) What math class will you be taking next year? OR What math class were you in last year?

3.) Are you interested in math and/or technology?

1	2	3	4	5	6	7
Not at all			Undecided			SUPER interested

4.) Do you have any experience with coding or software?

1	2	3	4	5	6	7
None whatsoever			Undecided			Taken a class (or multiple classes)

Any cool projects you've done?

5.) Have you ever been embarrassed to ask a question in class? If so why do you think that may have happened?

6.) If you have ever been getting a grade you were not happy with in a class, did it make you dislike the class?

1	2	3	4	5	6	7
Never happened			Don't care			HATED the class

7.) Do you consider yourself good at math?

1	2	3	4	5	6	7
Not at all			Somewhat good			I rock

8.) Do you consider yourself good with technology?

1	2	3	4	5	6	7
Not at all			Somewhat good			I'm an expert

9.) Do you like math?

1	2	3	4	5	6	7
Not at all			Don't care			LOVE IT, my favorite subject

10.) Do you like technology?

1	2	3	4	5	6	7
Not at all			Don't care			LOVE IT, my favorite subject

11.) Have you thought about what you want to major in in college? If so, what are some of your ideas?

12.) Do you think math is/can be fun?

Yes No

13.) Do you think technology is/can be fun?

Yes No

Figure 13: Pre-survey questions.

Post Experiment:

We are going to ask you some of the same questions as before, and some new ones. If any of your answers change, that is okay! If they don't change, that is okay too! We just want to see if today has changed any of your feelings towards math and technology.

1.) How would you describe your math skills (need more work, okay, great, awesome, etc.)?

1	2	3	4	5	6	7
Very poor	Need lots of help		okay/ satisfactory	good	great	excellent

2.) Do you consider yourself good at math?

1	2	3	4	5	6	7
Very poor	Need lots of help		okay/ satisfactory	good	great	excellent

3.) Do you consider yourself good with technology?

1	2	3	4	5	6	7
Not at all			Somewhat good			I'm an expert

4.) Are there things you would like to do with technology?

5.) What, if anything, interests you the most about math?

6.) What, if anything interests you the most about technology?

7.) What do you not know about engineering/computer science fields?

8.) What would you like to learn more about in terms of engineering/computer science?

9.) Would you consider going into a math or technology-related major in college?

1	2	3	4	5	6	7
Not at all			Haven't thought about it			yes definitely consider

10.) Do you like math?

1	2	3	4	5	6	7
Not at all			Don't care			LOVE IT, my favorite subject

11.) Do you like technology?

1	2	3	4	5	6	7
Not at all			Don't care			LOVE IT, my favorite subject

12.) Did you find what we did today fun? Be honest!

1	2	3	4	5	6	7
Not at all			Don't care			LOVED IT, would do it again

13.) What would have made today more fun?

14.) Did you learn anything new today?

Figure 14: Post-survey questions.