Coding Camp for Middle School Girls Helps Improve Awareness of Science/Engineering Careers and Pathways

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Abstract

Although jobs and career opportunities in computer science continue to grow rapidly, women constitute only 28% of the computer science workforce. There is an urgent need to motivate women at a young age to pursue careers in science and technology. This paper presents outcomes of organizing a summer camp for middle school girls (grades 6th to 8th). The camp was spread out over 6 weeks in a major city in the US and reached out to 120 girls with a different set of girls participating each week. Each week constituted as follows: Day 1 creating animations and stories using scratch; Day 2 physical computing (robotics) using LEGO Mindstorms; Day 3 creating games using scratch; Day 4 showcasing their work on Days 1 - 3 by creating a website using Kompozer; and Day 5 tour of a public urban-serving institution. The key pedagogical aspects of the camps were: (1) tasks conducted in groups using online resources and hands-on experiences; (2) creation of mentorship relationships between undergraduate engineering students and camp attendees; (3) competitions based on small projects to increase engagement. Pre- and post-camp survey on a 5-point Likert scale indicated that the girls showed increased awareness of science/engineering careers and pathways, everyday application of coding, and specific coding jobs that require coding. However, the camp did not change their attitude towards pursuing a career in science and engineering. Our results suggest that short coding camps might potentially increase awareness or coding jobs but may not generate long-term interest in pursuing science and engineering careers. Thus, our recommendation is longer exposure to computing, such as dedicated classes in computing in K-12 is essential to increase representation of minorities in computer science. All materials used in the camp is already available for free download on GitHub using this link: https://coderunners2019.github.io/

1. Introduction

Since the late 1990s women have earned half of the Science and Engineering bachelor's degrees but only 18% computer science degrees and 20% engineering degrees [1]. Similarly, although women make up for half of the total U.S. college-educated workforce, they make up only 28% of the engineering and computer science workforce [1]. There is a sustained gender disparity in the Computer Science and Engineering degree holders and consequently the workforce. Thus, there is a clear need to reduce this gender gap to ensure a balanced workforce. The best time to create such awareness is during the middle-school age [2].

Since the vast majority of schools in the United State of America do not offer dedicated coding or computer science curriculum, there is a critical need for short computer science camps [3]. It has been demonstrated that given the right resources girls can develop a liking for computer science [4] and develop their own identity as a computer scientist [5]. Short camps may increase knowledge and skills in computer programming [6]. There have been many attempts at teaching computer programming through hands-on activities such as programming computer games [7] [8], robotics using widely available kits such as LEGO Mindstorms [9], and using mobile app development [10]. It was found that girls are able to learn using graphical programming softwares [11] [12] as well as line-based programming environments [13].

This paper presents results of organizing a summer coding camp for middle school girls including coding material, pre- and post-camp survey and results, and suggestions for future camps. The overall motive of the summer coding camp was to create an awareness of computer science and engineering education and careers among middle school girls. The main objectives of the camp were: to introduce the girls to coding through hands-on activities and to create an awareness of computer science and engineering education and careers. The details of the summer camp follow in Section 2. Then we present the results of the pre- and post-camp survey in Section 3 results. The discussion follows in Section 4, followed by the conclusion and suggestions for future camps in Section 5.

2. Details of the summer coding camp

The summer camp was funded by a grant from a state agency responsible for the development of the workforce. The grant stipulated that all the participants should be girls from 6^{th} to 8^{th} grade.

The recruitment of girls took place via flyers at a community center, communication to middle school teachers, principals, counselors, and social media such as website, facebook, twitter, and whatsapp. The grant required us to encourage girls with disabilities, foster girls, low income families, and minorities. We had to ensure that 85% of the girls attended atleast 80% (4 out of 5) days. The girls and their parents had to complete a form that included their details, nomination from a teacher, and a consent form for photos/videography. There were no aptitude or prior interest questions in the application; girls who were interested in learning about coding were free to fill the application. Eventually, all girls who completed the application were selected; we did not reject anybody who met all criteria.

The summer coding camp was spread over 6 weeks. Each week ran from Monday to Friday and admitted a new group of 6th to 8th-grade girls. The number of girls per week varied between 12 and 30 but the final number of girls that took part in the 6 weeks was 116. The girls worked in teams of 2 or 3 for the entire duration of the week. The coding camp was held in a community center in a major city in the USA.

Each week covered the same content consisting of 4 days of coding days and 1 day of University campus tour. During the coding days, the girls learned how to use coding to create animations, games, webpages, and programming robots. During the tour day, they were escorted to a public university where they learned about the University activity and work done in a research lab. More details of these days follow. Figure 1 shows some of the interactions among girls during the animation day and robotics day.

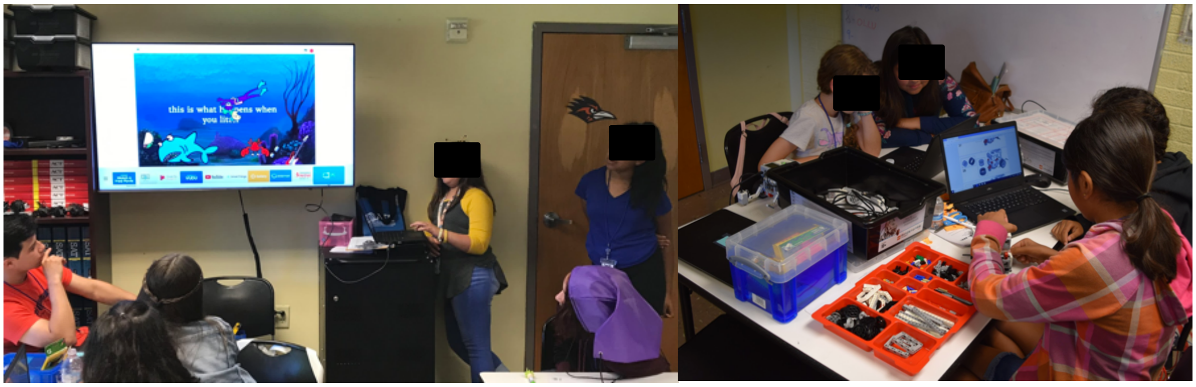

Figure 1: (left) A girl presenting here animated story to the class, (right) a group working on robot building.

Day 1 (Monday) Coding animations: We used the free coding environment scratch [14] for animation. Scratch provides a block-based visual programming language. The programming is centered on animated characters/objects called sprites that may be programmed to move, rotate, change the size, disappear/appear, make sound, and change looks. Also, the coding environment teaches the basics of variables, loops (while, for, if-else), logical operators, mouse interactions.

The girls first learned about basic usages of sprites by first looking at demonstrations provided by scratch followed by an exercise to create their own sprites to do multiple things (move, change shape, etc.). Then students were presented with two tasks: (1) make an animated greeting card; (2) make an animated story (see Figure 2). The student assistants made videos of their animations and uploaded them on YouTube. At the end of the day, all girls presented their card or story to the entire group of girls where voting was used to determine the best team animation (see Figure 1 (left)).

Figure 2: Student creations for (1) animated greeting card (2) animated story. See [17] for more.

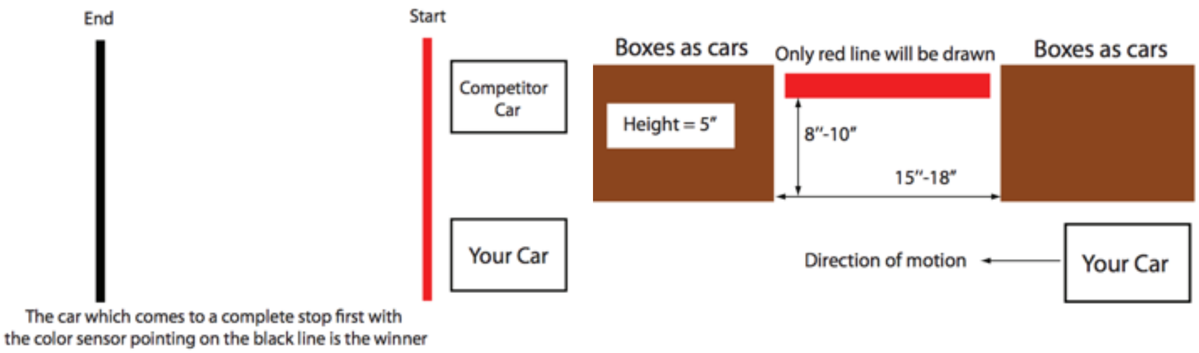

Figure 3: Instructions for the two robotics tasks: (1) car racing; (2) parallel parking. See [17].

Figure 4: Snapshot from the two robotics challenges: (1) racing, (2) parallel parking. See [17]

Day 2 (Tuesday) Coding robots: We used LEGO Mindstorms Ev3 education core set [15] for the robotics day. The LEGO Mindstorms set costs about $400 but the programming environment is free. The hardware provided by LEGO Mindstorms has modular blocks with attachment points including wheels to create robots. The kit also provides sensors, motors, and a programming brick based on an ARM9 processor. The programming environment consists of visual blocks (e.g., sensor and motor, loops, variables) that may be organized to create logical programs for the robot. The Figure 1 (right) shows the LEGO Mindstorms kit being used by a team.

The girls first learned about the programming environment by creating programs using the brick to take inputs from the color sensors and control the speed and direction of motion of the motors. Thereafter the girls were involved in two tasks as shown in Figure 3: (1) car racing; (2) parallel parking. The girls were provided with a design to make a differential drive car so the focus of these challenges was geared towards programming and not hardware. The student assistants made videos of their performance in the two challenges and uploaded them on YouTube so that they could share these videos through the website creation on Day 4. Figure 4 shows the girls' robots competing in the two challenges.

Day 3 (Wednesday) Coding games: Like Day 1, we used the free coding environment scratch [14] for coding games.

The girls first recalled the basics of scratch and had more exercises to learn how to create sprites that interact with the user through the keyboard. Thereafter the girls were presented two challenges: (1) create an educational game appealing pre-school kids (e.g., counting, colors, alphabets); (2) create a game of their choice. The student assistants made videos of their games and uploaded them on YouTube. At the end of the day, all girls presented their creation to the entire group of girls where voting was used to determine the best team game. Figure 5 shows two games created by the teams.

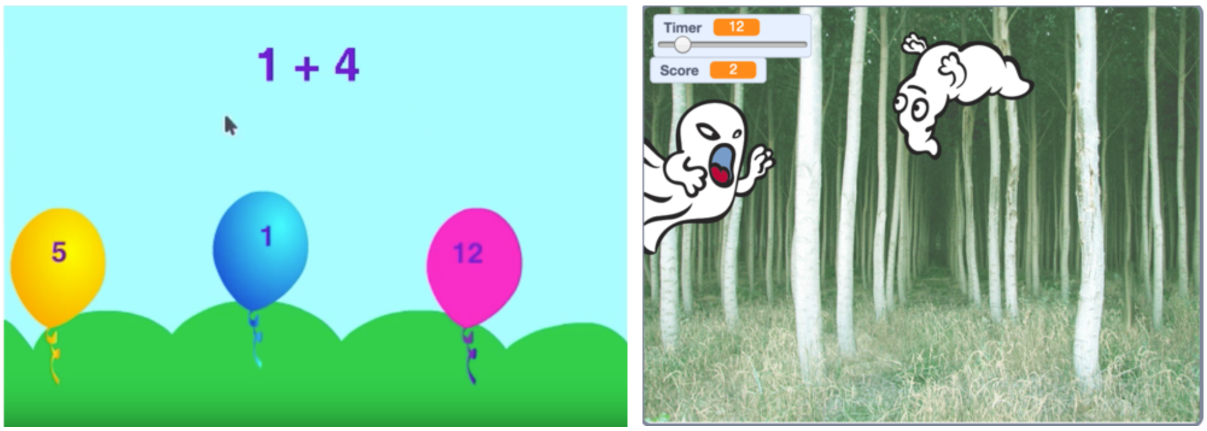

Figure 5: Students creation of (1) educational game (2) their own creative game. See [17] too.

Day 4 (Thursday) Coding webpages: We used the open-source HyperText Markup Language (HTML) editor Kompozer [16]. This is a What You See Is What You Get (WYSIWYG) editor in which contents are edited in a form that resembles how they will eventually look in the final product. They can edit the webpage using a graphical user interface. On the backend, program generates HTML code that may also be edited if needed (e.g., script to embed a YouTube video).

The girls first learned about the basic tools in Kompozer such as adding tables, images, adding links, embedding YouTube videos, creating lists, changing font size and color through a series of videos. Once they learned the basics, the girls created a group webpage which introduced themselves including things such as their names, hobbies, their favorite moves/actors/actresses, which profession they want to pursue, etc. and showcasing the work they did during Days 1, 2, and 3 of the camp. They did so by linking the games on scratch or embedding or linking the YouTube videos uploaded by the student assistants. Figure 6 shows the website of one of the teams.

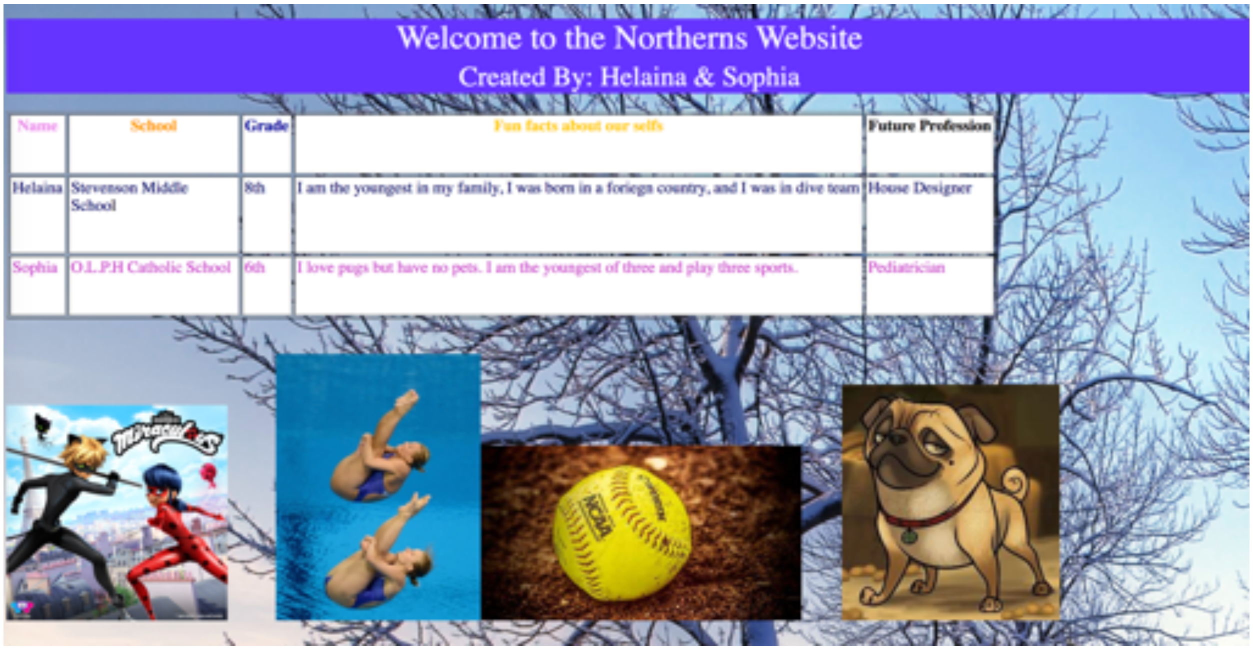

Figure 6: A webpage created by one of the groups. The girls were instructed to introduce themselves through the webpage. See [17] for more.

Day 5 (Friday) University Tour: The girls were shuttled by buses from the community center to the public university and back. At the public university, the girls toured a robotics lab followed by a tour of the University. In the end, each girl got a prize for participation and 4-7 raffle winners either got a Chromebook or an mp3 player as an additional prize. These raffles were earned by the girls during Days 1 through 4 based on performance. A better performance enabled them to win more raffles and increase their probability of winning the additional prizes.

3. Results

At the beginning of Day 1, the girls were administered a pre-camp survey. Then during each day, in the beginning, the students were encouraged to do an internet search to find the answer to a key question related to the contents for the day. Specifically, on the animation day, the online search focused on what an animation engineer does and how animations are made; on the robotics day the focus was on what robotics engineers do and robotic applications, on the games day the online search was related to gaming engineering and how games were created; and on the webpage design day, girls researched about webpage designers and how webpages are made. Then as the day progressed, the students learned about the basics of the programming environment followed by increasingly challenging tasks. At the end of Day 4 (last coding day), the girls were administered a post-camp survey that had identical questions as the pre-camp survey. We now present the results of the pre- and post-camp survey.

The total number of girls who took the pre- and post-survey was 100 and 116 respectively (post-survey was missed one week) including 49% 6th graders, 25% 7th graders, and 26% 8th graders.

Table 1: Results of pre- and post-camp survey. The survey was on a 5-point Likeart scale with: 1 – Strongly Disagree, 2 – Somewhat Disagree, 3 - Neither Agree nor Disagree, 4 – Somewhat Agree, 5 – Strongly Agree. See [17] for more.

Question		Pre-camp		Post-camp		
		Mean	Dev	Mean	Dev	p-value
1	I know what scientists do	3.83	1.11	4.11	0.76	0.1
2	I know what engineers do	3.62	1.37	4.09	1.01	**0.007**
3	I know about different engineering career choices	3.17	1.54	3.83	1.29	**<0.001**
4	I know about different scientist career choices	3.39	1.46	3.83	1.16	**0.019**
5	I want to pursue a career on Science	3.1	1.59	3.02	1.61	0.8
6	I want to pursue a career on Engineering	2.83	1.58	2.95	1.76	0.34
7	I know everyday applications of coding	2.7	1.29	3.7	1.12	**<0.001**
8	I know about specific jobs that require coding knowledge	2.91	1.21	3.56	1.18	**<0.001**
9	I know about specific majors/pathways that require coding	2.85	1.25	3.52	1.2	**<0.001**
10	I know about common features of animation, storytelling, robots, computer games and websites	3.25	1.29	3.91	1.14	**<0.001**
11	I know about creating animations and stories	3.11	1.23	1.94	2.39	**<0.001**
12	I know how coding is applied to make robots do tasks	2.99	1.31	2.17	2.3	**0.009**
13	I know how coding is applied to create computer games	2.69	1.27	2.38	2.36	0.26
14	I know how coding is applied to design websites	2.9	1.39	2.18	2.17	**0.007**
15	I am excited to learn about coding animation/storytelling	3.87	1.5	3.89	1.29	0.52
16	I am excited to learn about coding robots	3.88	1.45	4.04	1.43	0.3
17	I am excited to learn about coding computer games	4.09	1.52	4.22	1.22	0.93
18	I am excited to learn about coding websites	3.63	1.68	3.75	1.46	0.96

The girls were asked 18 questions on a 5-point Likert scale. These questions are indicated in Table 1. The 5-point scale was given a numerical value: 1 – strongly disagree; 2 – somewhat disagree; 3 – neither agree nor disagree; 4 – somewhat agree; 5 – strongly agree. The mean and standard deviation are shown in Table 1. We used a Wilcoxon Rank Sum Test to compute the test statistic, the p-value. We use a p-value of 0.05 to interpret the results. The null hypothesis is that the median of the pre- and post-camp is the same while the alternate hypothesis is that they are not. A p-value less than 0.05 would indicate that the null hypothesis should be rejected. In other words, the coding camp had a significant effect in changing the perception of the campers.

Q1 to Q 4 is about the girl's perception of what scientists/engineering do and related career options. As seen from the Table, the mean pre-camp was between 3.2 to 3.8 and increased to 3.8 to 4.1 post-camp. This is further enforced by the p-values < 0.05 for Q2, Q3, and Q4 indicating an increase in the awareness.

Q 5 and Q 6 gauges the attitude of the girls in pursuing a scientist/engineering career. We can see that the mean and deviation remained changed and the p-value > 0.05. This indicates that the camp was not able to positively change the mindset of the campers to pursue a science/engineering career.

Q7 to Q10 gauge girls' awareness of the everyday application of coding and about jobs/careers/pathways in coding jobs as well as common elements of different aspects taught in the camp. Again, it can be seen that the mean increased from 2.7 to 3.25 pre-camp to 3.7 to 3.9 post-camp and p<0.005 indicating that the camp was quite successful in increasing the girls' awareness of these areas.

Q 11 to Q 14 gauge if the girls were able to improve their content knowledge of the coding application to animation, games, robotics, and webpage design. It can be seen that the mean decreased from 2.7 to 3.1 pre-camp to 1.9 to 2.4 post-camp. This indicates that the girls overestimated how much they knew about coding pre-camp and that the coding program introduced them to new knowledge. Thus, post-camp they seem to have left with the impression that there is more toward coding then they knew pre-camp. Since the p-value > 0.05 for Q13 indicates that the girls were aware that coding is required for creating computer games. However, since p<0.05 For Q11, Q12, and Q14, indicating the the camp made the girls aware that coding is used for robotics, storytelling, animations, and websites.

Finally, Q 15 to 18 gauge's the girls' excitement toward coding applications to animation, games, robotics, and webpage and the mean indicates a slight increase in the interest ~0.1 to 0.2. The p-value > 0.05 shows that camp did not increase their excitement significantly.

Another question asked the girls to choose what engineering they would pursue. Figure F gives the results pre- and post-camp. The y-axis is the percentage value and the x-axis indicates the different choices. About 30% of the students were not interested in Engineering pre-camp and that number increase to 35% post-camp. The relative percentages in the fields were almost unchanged.

We asked the following question at the pre-camp survey.
Q1. What do you expect to learn from this camp? The answer to this question was predominantly on coding one or another topic that was going to be covered in the camp.

Also, we asked the following questions at the post-camp survey
Q1: What did you like the most about the camp?
Q2: What did you like the least about the camp?
Q3: How do you think we can improve this experience for future students?
Q4: This camp code for girls is funded by the workforce commission of the state. Please share any comments you would like us to pass to the sponsor, specifically on how this camp has helped you to consider careers in engineering or science.

For Q1, the students responses were the clear instructions, helpful TA's, the hands-on-activity, the trial and error approach to learning, food, meeting new people. For Q2, the student responses were typically that they did not like one of the 4 activities (Robotics seemed to the least favorite, followed by gaming/animation, and finally website design). For Q3, students said they would like more lecturing, more help with coding, interactions between different teams, easier exercises and more resources for robotics or just remove robotics, more accessible location, more breaks, and some also felt that there should be more advanced coding languages like python, ada, and java.

All student replies to these questions are in the reference [17].

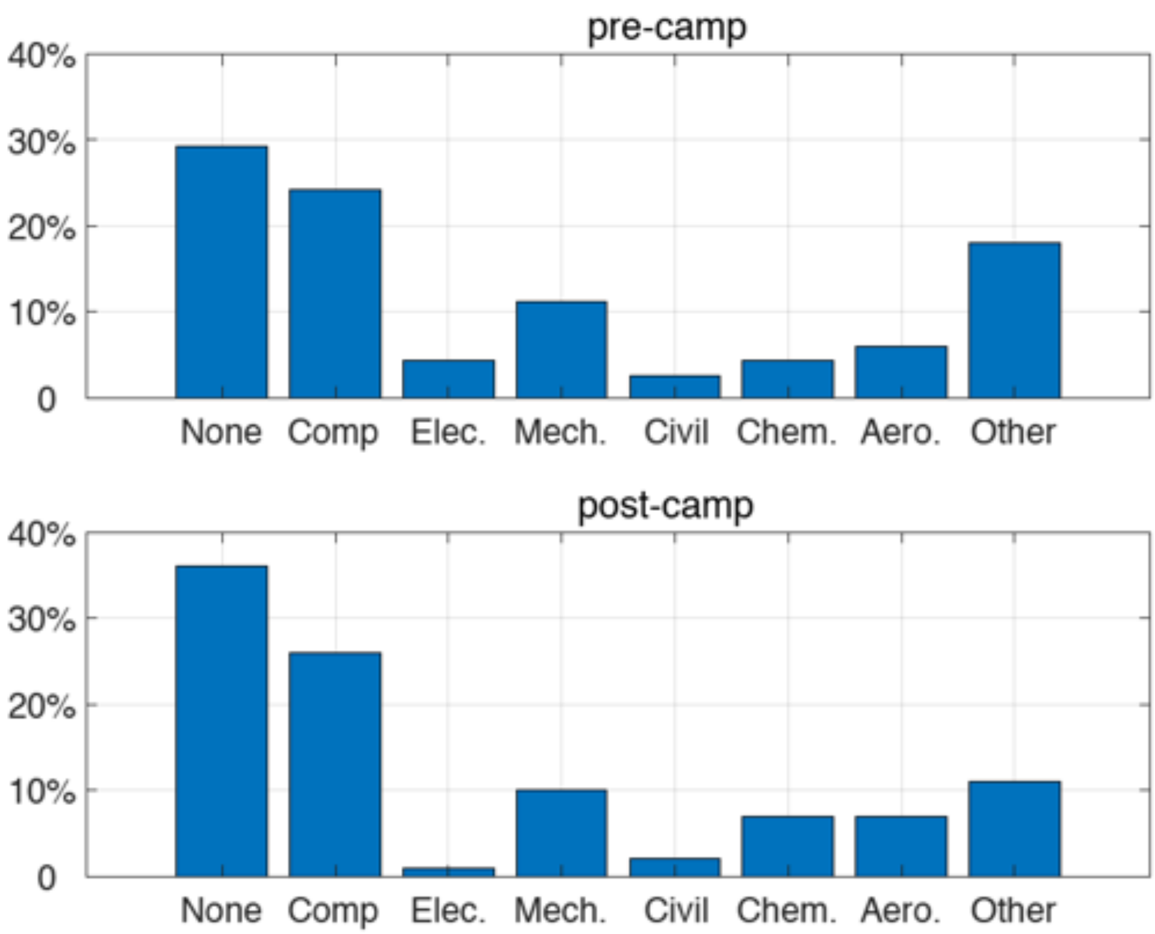

Figure 6: Results of pre- and post-camp survey answers to the question: What kind of Engineering do you want to pursue? See [17].

4. Discussion

The paper gave an overview of the coding camp for middle school girls including pre- and post-camp survey questions and responses. All code camp material is posted on GitHub [17]. The main aim of the coding camp was to introduce middle school girls to coding to foster an interesting careers in coding/programming encourage them to pursue careers in coding/programming in the future. The main takeaways from the pre- and post-camp survey were that the coding camp

- increased awareness of what scientist/engineers do
- increased awareness of different scientist/engineering career choices
- increased awareness of everyday coding applications
- increased knowledge of jobs that require coding and job pathways
- increased knowledge of creating games/animations/robotics/web design
- did not change excitement toward coding for games/animations/robotics/web design
- did not change attitude to pursue a career in science/engineering

The sponsor of the program had the stipulation of introducing the middle school girls to coding through a week-long program. Instead of keeping the entire coding camp focused on a single coding topic (e.g., web design or animation), we decided to have a new topic on coding every day. We think that this is a better idea to keep the girls focused while introducing them to a wide variety of coding topics to better expose the girls to related careers.

The camp sessions were designed to balance lecturing, independent research and teamwork. Thus, lecture time was kept at a minimum to allow for more interaction among the girls. However, each group of girls was assigned to a teaching assistant who helped the girls as needed.

The big advantage of using online resources and hands on tasks is that it allows the girls to take ownership of their learning, as well as have a more meaningful experience as they learn by doing. It is recommended that online resources are concise and address the content relevant to the assigned tasks. The camp organizers made a selection of the online resources in advance, so the girls had the resources already identified. All the online resources were uploaded by people other than the camp organizers. However, it is important to have short video clips of about 2 to 4 min as longer videos may have too much content or too many instructions that are difficult to follow. It is better to have multiple short videos on individual topics than a single complex video on multiple topics. Finally, none of the videos were made by us; we relied on videos made and uploaded by YouTube users.

The teaching assistants were mostly undergraduate/graduate engineering majors. We had a good mix of students, including those that identified themselves as women/men and also African-American, Asian, Hispanic, and Caucasian. This mix was vital to impress the girls that engineering is pursued by people of all races/sexes. Since one assistant was linked to a group of students for the entire duration of the camp, there were interactions beyond the content of the camps that included how/what/why these assistants took on engineering careers. We believe that this aspect of our camp may influence the girls to consider STEM careers.

To maintain high levels of engagment and attendance, the girls were promized certificates and prizes at the end of the camp (see Figures 7). We explicitly stated on day 1 that girls who attended 4 out 5 days of the camp will get a certificate and a take-away gift. This gift was a kit costing $20 on how to make movies. Another reason for ensuring 80% attendance was that our sponsor required this much attendance. Also, for completing the tasks and winning the competition or getting voted the best project for the day, the girls got raffle tickets. These tickets were then entered (on the last day) for an additional prize. These additional prizes were either a google Chromebook worth $150-$200 or an mp3 player worth $20.

Our camp had some limitations too. Although we planned to involve parents in the camp by having a STEM career session we were unable to execute this piece because our camp was held Mon to Friday (i.e., on working days). We consider that for future implementations, online resources about STEM careers can be provided to parents to address the limitation of meeting in person. Our sponsor required 6th to 8th-grade girls only hence we had to turn down girls from other grades. Thus, although we targeted 150 girls we were only able to have a total of 116 girls spread over the 6 weeks. This was in spite of inviting all girls who met the criteria and who completed the application process. Some of the free responses from the girls indicated that our robotics day was the most challenging with little time, the competitions were stressful or were not favored by some, and lack of interaction between the groups during the exercises. Finally, we could have potentially analyzed the pre- and post-survey data on a weekly basis to fine tune the questionnaire in order to do sensitivity analysis.

Figure 8: (left) Lab tour on the last day (right) a girl receiving a chromebook

We summarize key ideas that worked for us and lessons learned.

1. **Pair engineering-student instructor with a group:** Each group had a dedicated engineering-student instructor that interacted with the group of girls for the entire week. This was a great way for the girls to get guidance and also learn about engineering education and careers.
2. **Provide scaffolding:** The scaffolding provided was in the form of small activities that the girls had to complete as they were doing the online search. Each video was followed by a set of activities that the girls had to perform and check in with the teaching assistants before moving on to the next activity. Thus expectations were laid down and time limits were also set. The teaching assistants who were assigned to the table were also able to closely monitor and help the girls as needed. Using feedback from the teaching assistant we tweaked the instructions. By week 3 the instructions were fairly mature and no changes were done.
3. **Have instructors to guide rather than teach:** Our model for teaching was based on learning by doing and scaffolding rather than a series of lectures. Thus, the instructors were there to facilitate the collaborative learning that happened as the girls practiced and applied the videos that they watched. This ensured that the girls were more focused on the outcomes and self-driven.

4. **Good food is important for day camps:** During the 5-hour camp from 9 AM to 2 PM, we had two breaks for food: a short 15 min snack and stretch break at around 10:30 AM and a lunch break of 30 min from 12:00 to 12:30 PM. For the snacks, we had assortment of bars, chips, fruits, and water. For the lunch, we ordered food from outside and was either sandwiches, rice-meat, chicken nuggets, or pizza and a small sweet such as a brownie, ice-cream, cookie. We varied the meals so that there were no repeat meals at any day. We believe that good food contributed to maintain an almost 100% attendance in the camp. We were also careful to keep track of girls with food allergies and plan alternate meals for them.
5. **Use software appropriate to the age group:** Since we were targeting middle school girls we did not expect them to have prior program experience. Thus, we resorted to the most basic coding software. This was scratch for animation/gaming, LEGO for robotics, and Kompozer for webdesign. The common feature of these software was their easy to use drag and drop graphical user interface. Thus, our focus for the coding camp was to train the girls on algorithmic aspect of coding such as loops, variables, input/output, logical operations, mouse interfaces and not specific aspects of programming (e.g., line programming in python or java).
6. **Check hardware infrastructure:** The hardware for animation/gaming/web-design was a Dell laptop (~$500) and for the robotics, it was LEGO Mindstorm Education Set (~$400). Each team of 2 or 3 girls shared the Dell laptop and/or LEGO Mindstorm Set. Also, we had a 2 to 3 extra kits for emergencies. Although all software was locally installed on the machine, we relied on internet access to conduct the online research. In case the internet was down (this happened only on one day) we did have all the online resources on a thumb drive.
7. **Find ways to ensure students attend:** Since we had a free camp, we were worried that we may not have full attendance for the camp. Our sponsor stipulated 80% (4 out of 5 days) attendance for 90% of the campers. To ensure the girls attended, we gave out an animation game to everyone who attended 80% of the camp. Also, we created a system where the girls won raffle tickets for participating in the events of the day and lucky winners from the raffles collected over the entire camp would entire to win either a Chromebook or an mp3 player. As a consequence, our camp was almost 100% full for the entire duration.
8. **Taking the camp to the community:** The coding camp was held in a community in a major city that is under-represented in terms of professional engineers. Thus, it was more impactful to take the camp to the community as opposed to organizing the event in the University. This community place we chose had a history of partnering with the University and this helped in securing a spot. Also, we budgeted some monies to pay the community center.
9. **Parents awareness of STEM careers:** Our initial plan was to have the final day of the camp on a Saturday. On this day, we would invite the parents and the children and inform both of them about STEM pathways and careers. However, as the community center was closed on Saturday we were unable to get parents to the camp. We did send the parents a STEM pathways and careers information sheet and a survey but got a very low response. We felt that this parent piece was important for families to consider STEM careers for their children.

5. Conclusion

Our main conclusion is that short coding camp can increase the knowledge and awareness of coding careers and jobs. However, a short coding camp was not able to change attitude towards pursuit of scientist/engineering careers (see Table 1 Q5 and Q6 and discussion following the table). To sustain long term interest in pursuing coding careers, we hypothesize that longer camps spread over one or more academic years to be ideal.

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