Control Systems and Robotics Outreach to Middle-school Girls: Approach, Results, and Suggestions

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Abstract

We conducted a three-day outreach camp focused on control systems and robotics for 8^{th} grade girls from economically disadvantaged families. The overall objective of the camp was motivating the young girls to consider pursuing a career in engineering and sciences. The main focus of the camp were hands-on labs using LEGO Mindstorms EV3 kit. Students learned about programming, sensors, motors and put their skills to test by creating a mobile robot that took part in three contests: car racing, line following, and parallel parking. A pre- and post-camp survey indicated that although program did not predominantly change the girls' excitement towards careers in engineering and sciences, it increased the girls' knowledge and excitement towards robotics and control systems. Our results indicate that short camps help kindle the interests of young girls, but are not able to sway them to take on engineering/science careers. In the latter case, we hypothesize that long-term STEM-based programs (e.g., a quarter or year-long robotics course) might be more effective.

1. Introduction

There is significant gender disparity in Science, Engineering, Technology, and Math (STEM) higher education and workforce. Although woman earn 50.3% of science and engineering bachelor's degrees, only 17.9% major in computer science, only 19.3% in engineering and only 29% of science and engineering workforce is made up of women [1]. There is a clear need to reduce this gender gap in STEM by arousing the interests of young girls to take on science and engineering careers. In this paper, we report on an outreach camp that we organized, results of the pre- and post-camp surveys, and provide suggestions for future camps.

The overall motive of the outreach program is to create an awareness about controls and robotics to motivate young girls to pursue careers in STEM. The program involved a three-day controls and robotics camp organized by the College of Engineering at the University of Texas at San Antonio (UTSA) with funding from the Institute of Electrical and Electronics Engineers (IEEE) Controls System Society (CSS) [2]. All the 85 participants were 8-th grade girls from Young Women's Leadership Academy (YWLA), a magnet public-school in San Antonio Independent School District. A majority of the girls who attended the program were from economically disadvantaged families. The objectives of the outreach camp were:

1. Introduce the girls to IEEE, CSS and their missions and objectives.
2. Introduce the girls to UTSA in general and to the College of Engineering in particular.
3. Create an awareness of the need for woman to take on STEM careers.
4. Create hands-on labs to teach controls and robotics.
5. Motivate the girls to pursue a career in engineering and/or sciences.

Fig. 1: A team showing their robot and all participants displaying their certificates at the conclusion of the camp.

2. Outreach program

The outreach program stretched over three days – a short first day and two full days. The first day (**Day 1**) included introduction to: IEEE CSS by the organizers, College of Engineering by the Dean, and Electrical and Computer Engineering by the Department chair; personal annals of a former UTSA woman student; and lab tours. The next two days (**Day 2** and **Day 3**) included hands-on activities using LEGO Mindstorms EV3 kit. The girls were divided into groups of 4 or 5. There were a total of 21 teams and were split into 3 classrooms for the program. Next, we describe the specifics of the program and activities. Figure 1 shows one of the teams and all the girls holding their certificates at the end of the camp. A video of the main activities is available on YouTube [3] and lab handouts and survey questions are available on Github [4].

2.1 Equipment

We used the LEGO Mindstorms Education EV3 Core Set. Only the following elements from the Core set are needed for the labs: the microprocessor also known as the brick with rechargeable battery, 2 big motors, 1 touch sensor, 1 color sensor, 1 ultrasonic sensor, 1 gyro sensor (optional). In addition, we purchased the infrared sensor as it is needed in conjunction with the color sensor and ultrasonic sensor for the parallel parking contest.

2.2 Hands-on activities

The two-day hands-on activities had two sessions per day or a total of 4 sessions as given below.

Day 2 – Morning session: First, the girls filled a pre-camp survey. Next, they were introduced to the equipment for the labs. This was followed by a series of tasks that included learning to program the brick, interfacing sensors and controlling the motors. The girls learned how to work with the kit by watching short YouTube videos. While we provided links to videos for some tasks, the girls had to search the Internet for others.

Day 2 – Afternoon session: The girls built a differential drive car and then programmed it to move in prescribed fashion (move straight, turn, et cetera). The day ended with a car racing competition shown in Fig. 2. The objective was to reach and stop at the finish line shown in red in the shortest time possible. The girls were allowed to use only the color sensor.

Day 3 – Morning session: The girls programmed their mobile robot to perform line following as shown in Fig. 3. They were only allowed to use the color sensor. Through this lab, the girls learned about feedback control, a well-known control technique that uses errors between desired value and the measured value to change the control signal. The lab was graded based on the following formula:

Score = 100 – time taken (seconds),

and a zero score for not completing the course. The girls had three attempts to improve their scores. All teams were able to cross the course at least once and the best time was around 11 sec.

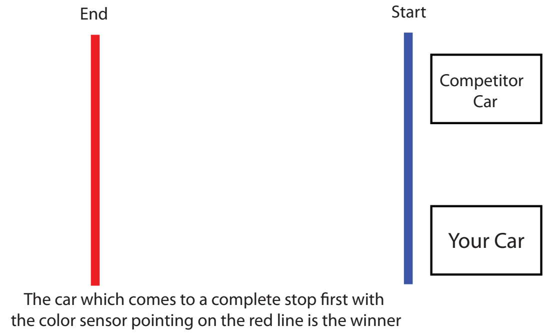

Fig. 2: Car racing

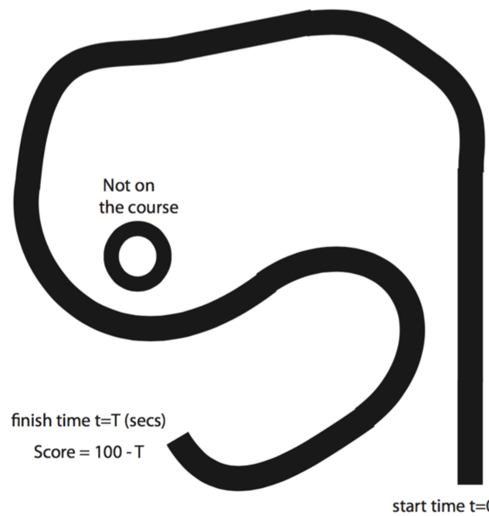

Fig. 3: Line following

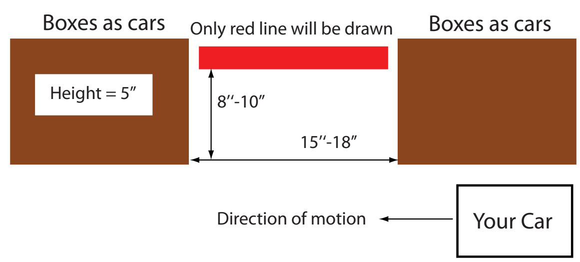

Fig. 4: Parallel Parking

Day 3 – Afternoon session: The girl first completed the post-camp survey. Next, they programmed their mobile car to parallel park. The course is shown in Fig. 4. Two LEGO boxes were proxy for the parked cars and a red line indicated the curb. The students were allowed to use any number of sensors from the LEGO box but were not allowed to share sensors from others. The lab was graded based on the following formula:

Score = 40 points (not hitting front and back car)
+ 20 points (for not crossing the red line)
+ 20 points (for parking parallel to the red line)
+ 20 points (for parking with at least one tire on the red line)
– time taken (seconds).

The girls had three tries to improve their score. In order to be successful, one needs to use the color sensor to detect the red line and two proximity sensors (infrared and ultrasonic sensor) to detect the parked cars, and optionally the gyro sensor to check orientation after parking. The control concepts learned from this lab were how to use sensor data to make decisions. This was a relatively hard lab with most teams using pre-played commands rather than using sensors. None of the teams were able to achieve all objectives and only one team managed to get 80 points (excluding the time taken) in one of the attempts

The scores from the line following and the parallel parking contest were added up to decide prize winners. The first two teams in each classroom (there were 3 classrooms) were given a cash prize, $30 per girl. All girls were awarded a participation certificate signed by the Dean of the College of Engineering of UTSA (see Fig. 1).

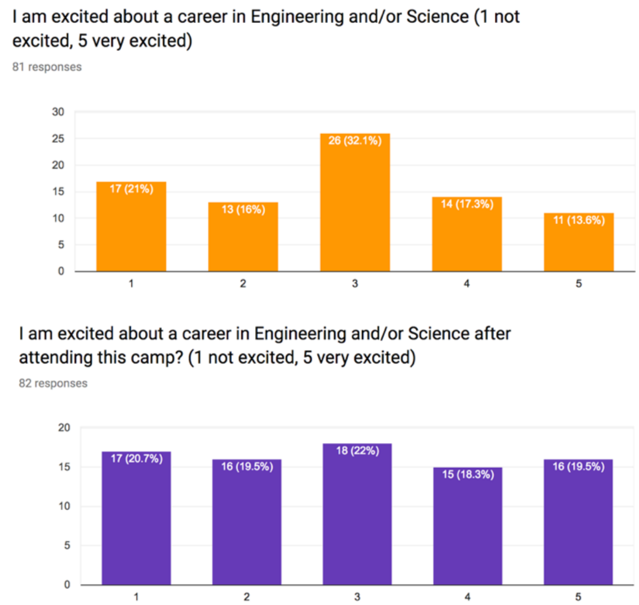

Fig. 5: Attitude towards pursuing a career in Science / Engineering, pre- (top) and post-camp (bottom)

3. Results

We present some of the result of the pre- and post-camp surveys. Fig. 5 shows the attitude towards engineering pre- and post-camp on a scale of 5 with 1 indicating not excited about engineering and 5 indicating very excited about engineering. The mean was 3 pre- and post-camp. Thus, our preliminary conclusion is that the excitement level towards an engineering/science career was unchanged.

Figure 6 shows the excitement towards the topics of the camp, robotics and controls, pre- and post-camp with 1 indicating not excited and 5 indicating very excited. The main changes observed here were: the not excited group decreased from 29% to 17% (rating 1 and 2), the neutral group increased from 33% to 42% (rating 3) and the excited group increased from 30% to 42% (rating 4 and 5). From the basis of these plots, we conclude that overall, the excitement level towards robotics and controls was increased by the camp.

Figure 7 shows some of the reasons why students want to pursue engineering careers. It is interesting to note that only 7% of students had role models who were engineers/scientist and about 31% were not interested in engineering/science. However, we also noted that about 9% of the students were unclear on what careers they might want to pursue, thus the actual percentage of students who were not interested in science/engineering is about 24%.

Figure 8 shows students' perception on knowledge gained in robotics and controls after the camp. From the graph, it is seen that an overwhelming large, 77% of the students felt that they learned new things (rating 3, 4, and 5).

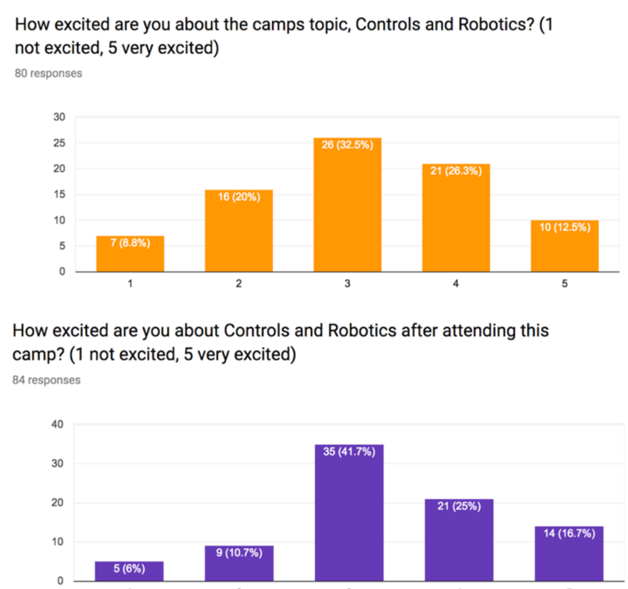

Fig 6: Excitement about Controls and Robotics pre- (top) and post- camp (bottom)

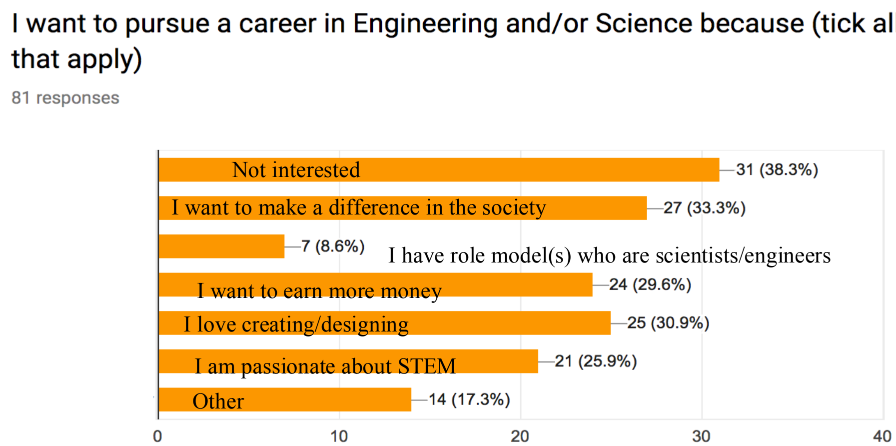

Fig. 7: Interest in pursuing Engineering and/or Science careers, pre-camp survey

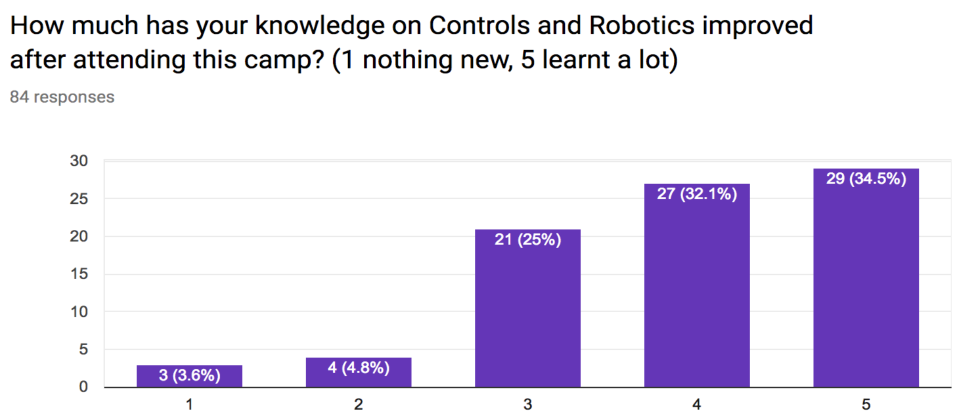

Fig. 8: Student's perception of learning outcomes post-camp survey

4. Discussion

We have presented an overview of an outreach camp we organized that aims to increase awareness about STEM in general and controls and robotics in particular. We targeted middle school girls from economically disadvantaged families. Although the overall excitement towards engineering was unchanged after the camp, the girls were more excited and learned more about robotics and control systems as a result of the camp.

There were several interesting things that we observed during the course of the camp. Majority of the girls had never programmed before, yet were able to quickly learn programming. This is in part due to the simple drag and drop feature of LEGO Mindstorms EV3 software which is based on the National Instruments LabVIEW software. We found that providing students with video instructions, namely YouTube videos created by other users were very effective. Learning using online videos has been documented as an effective pedagogy [5]. It is well known that having role model can improve students interest in STEM [6] but only 7% of the students had role models who influenced them to pursue career in engineering and science. We had 8 teaching assistants (TA's), out of which three were instructors and had extensive experience working with the LEGO kits. This is highly desirable as they were able to quickly help the students in case of issues and provide additional help. The other instructors had some but not extensive experience. Also, the TA's included 2 women and 3 Hispanic men. The ethnic matching of TA's to the students has been shown to provide a positive influence of the interest of girls towards STEM topics [7].

It is important to keep the young students who are learning new tools interested in what they are doing. This was achieved in a number of ways. (1) We used real-world applications for the labs. For example, line following robots also known as autonomous ground vehicles are extensively used in industries for pick and place. (2) We used competitions [8]. The car racing event involved competing with peers and generated a lot of excitement. (3) We created labs which the students could relate to. For example, most girls did know (and some had tried) parallel parking before and knew it to be a difficult task. Thus, they were challenged to solve the problem using the kit. (4) We announced and gave out cash prizes, which motivated the girls to try their best. Another example of a successful program based on competition, real-world examples, and prizes is the FIRST LEGO League [9].

Our camp had its limitations. On the first day, we had multiple long speeches and it was pointed out as a negative by multiple girls in the post-camp survey. The other comments included: have a longer camp camp, have shorter sessions, the labs need to have more explanations, have diverse assignments such as building walking robots.

5. Conclusion

Our conclusion is that a short camp with hands-on activities can positively influence middle-school girls' attitude and excitement towards controls and robotics, but it cannot influence them to pursue a science or engineering career. Thus, we hypothesize that sustained STEM programs such as a year-long robotics course, might be more influential in persuading young girls to take on science and engineering careers.

We end the paper by giving some suggestions for future camps:

1. **Have experienced people handle the logistics:** While we worked on the scientific/engineering aspect of the workshop, the logistics aspect (certificates, catering, communicating with the school) was taken care by the outreach office in the College of Engineering. This, although came at a financial price, made the workshop easier to manage.
2. **Provide clear lab instructions:** We ensured that instructions for the labs were clearly written. This included providing links to the videos, giving set of tasks to the girls and then having the teaching assistant evaluate the students, logistics, et cetera. The labs are available here [4].
3. **Create reasonable hands-on activities:** Create labs that are reasonable in terms of time and effort needed. We have found that students are excited about labs when they have practical value (e.g., parallel parking), involve fun activities (e.g., car racing), and are doable under time constraints (e.g., we provided step-by-step instructions on how to build the mobile car).
4. **Prizes:** Giving out cash prizes and announcing them well in advance leads to tremendous self-motivation to perform well in the camp. It is also important that all rules and regulations are set well ahead of time and explained clearly. No rules should be changed as it can lead to undesired animosity. We have found that using language such as "In case of ambiguity, the instructor's decision is final" may help resolve conflicts.
5. **Check infrastructure/tools well in advance:** It goes without saying that all computers and kits need to be checked in advance. Also, be ready with a few spares for emergencies (e.g., broken sensor, brick).
6. **Cost:** The workshop cost was $10,000. This included in the decreasing order of costs: catering for three days, logistics, instructor/teaching assistants, cash prizes, and reserving rooms for the event. A significant cost could have been the LEGO Mindstorms EV3 kit (cost is $400 per box) but we reused the kit from an undergraduate robotics class thus making the camp viable.

Acknowledgement

This work was funded by a grant from IEEE Control Systems Society (CSS) with cost sharing from the Department of Electrical and Computer Engineering and Mechanical Engineering. The authors would like to thank Daniel E. Rivera, Chair of the IEEE CSS Outreach Task Force for his encouragement, Roberta Bauer and Katherine Alexander from iTEC at UTSA for their help with logistics, Delia McLerran, Principal of Young Women's Leadership Academy for her help with recruitment of the students, and to the following students for serving as instructors and teaching assistants: Lindsey Fett, Julian Salas, Sebastian Nugroho, Eric Sanchez, Joseph Galloway, Steven Farra, Diane Squire, and Gerardo (Aaron) Rios.

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