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Inspiring Girls to Pursue Careers in STEM with a Mentor-Supported Robotics Project

Abstract

This paper describes an innovative program with Lego Mindstorms NXT designed to interest young girls in careers in Science, Technology, Engineering, and Mathematics (STEM). A female engineering graduate student mentored the girls registered in the program on a monthly basis at their schools over eight months. The mentor designed a fun robot competition for the girls, for which the girls were free to build any design of robot they thought appropriate using the parts from one Mindstorm kit. The competition was part of the IEEE Western Canadian Robot Games held in May 2010. Surveys were conducted at the beginning and end of this program to measure girls attitudes towards STEM careers, in order to gage the effectiveness of this program.

1 Introduction

In this paper, we explain the project we created for female students aiming to increase their awareness of engineering, and in particular robotics, as a potential career. Recently, academia has started placing great emphasis on trying to increase the number women in science, technology, engineering and math (STEM) university programs and careers [1]. Many hands-on programs have been launched for school-age girls to try and introduce engineering concepts and enthusiasm at an early age. Especially, robotics has been a popular platform for accomplishing this. Some programs, like MIT’s [2] and NASA’s [3] have engineers working with robotics and girls, but not actually in the girls’ schools. A number of studies have been undertaken of classroom teachers working with girls and robotics; however, too many teachers quickly hit the limits of their knowledge and expertise [4]. Some have evaluated programs aimed at bringing robotics into the classroom in a more formal manner, and found evidence of the effectiveness [5, 6, 7]. Our project differs from those described above by avoiding a highly structured program, but rather having a unstructured design project geared for a robot competition. In addition, the girls are supported in their own school by a female engineer serving as a mentor.

The idea of introducing K-12 engineering education is controversial. A new research book published by The National Academies Press [8] encourages giving up on the idea of teaching engineering ideas in K-12, stating “The committee concluded that, although it is theoretically possible to develop standards for K-12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation. This conclusion is supported by the following findings: (1) there is relatively limited experience with K-12 engineering education in U.S. elementary and secondary schools, (2) there is not at present a critical mass of teachers qualified to deliver engineering instruction, (3) evidence regarding the impact of standards-based educational reforms on student learning in other subjects, such as mathematics and science, is inconclusive, and (4) there are significant barriers to introducing stand-alone standards for an entirely new content area in a curriculum already burdened with learning goals in more established
domains of study.” Part of the aim of our project is to show that K-12 engineering education is indeed possible, and is implemented in such a way as to overcome objections (1),(2), and (4) above, while trying to lend evidence to refute objection (3).
Specifically, a female engineer (graduate student) served as a mentor for a group of girls from Sept. 2009 through May 2010 in four different schools. During this time the girls designed and built their robots for a particular “Treasure Hunt” competition. The mentor visited the schools once a month, although the girls met to work on their robots (with teachers) once a week at least. We surveyed the students near the beginning of the program and at the end to gage the effectiveness of the program in improving girl’s attitudes toward STEM careers and learning about robotics engineering. The survey responses confirm that this type of program is effective.

2 Description of the mentoring program

An MSc student (first author Sanaz Mahmoodi Takaghaj) served as a mentor for the students, with occasional visits by her supervisor (second author Chris Macnab). We worked with students at four schools, visiting each school once a month. Each school is a public school, but three of them are so-called Calgary charter schools who are allowed to provide specially-oriented programs within the public system. One school is a girls-only school, where we worked with a regular classroom of all girls. One school is a science-oriented school, where we worked with a regular classroom of boys and girls in equal number. One school is for Canadian Aboriginal children where we worked with boys and girls in equal numbers in a (small) classroom. In one school, not a charter school but beside the university with generally well-educated parents, we worked with only girls in a lunch-hour robot-club (the split was made between boys and girls in the club for the sake of our project).
The schools participating in the program already had their own Lego Mindstorms kits (Figure 1), and some teachers were already familiar with them, including basic programming. We held a 3-hour training workshop at the University of Calgary in September, mainly for the teachers who were unfamiliar with the kits. After the sessions, the teachers said they felt comfortable with the kits and we did not receive any further requests for information or training.
These Mindstorm kits include small motors, simple sensors, wheels, gears, and everything the student needs to construct a robot. They also include the USB cables making it possible to connect the robot to a personal computer to download a program into the device. The programming can be done in a graphical environment, by dragging and connecting different kinds of instruction and decision blocks.

The mentoring took place from October through April. At the beginning, we let the students familiarize themselves with the Lego and practice building and programming. After exposing students to a gripper hand robot made out of the LEGO Mindstorms kits, we asked them about their favorite robots. The answers were very impressive. While boys preferred fighting robots that can compete with each other, girls showed interest in building robots that can clear their room or feed their pets. After all students got familiar with building and programming the LEGO robots, we prepared them to participate in a Treasure Hunt game competition based on what they already had learned. In November we presented the rules of the Lego Mindstorms treasure hunt, and explained that they were to build robots to compete in this competition at the IEEE Western Canadian Robot Games in May. The mentoring then focused on helping the kids think through design ideas, help with practical building and programming issues. Although the mentoring only took place once a month, the students worked on their robots at least once a week under their teacher’s supervision.

3 The Treasure Hunt Game

The robot in the Treasure Hunt game must clean debris off a field, while looking out for a treasure. The robot tries to sweep pieces of debris, specifically gray and black Lego gears, off of a field. A black border outlines a white surface (Figure 2) While moving the debris the robot keeps an ‘eye’ out for the treasure, signals if it finds the treasure, and can try to pick up the treasure for extra points. Play stops when time runs out at 5 minutes, or when the robot has cleared all the debris and picked up the treasure.

The specifications for the playing surface were:
- White paper on top of a hard (wood) surface.
- Black tape denotes the edges of debris field.
- Debris field is 92 x 183 cm (3 x 6 feet).
Edges of the playing field cordoned off with two-by-fours, 1.5" wide by 3.5" high.
Total field size is 122 x 244 cm (4 x 8 feet).

The scoring rules were specified as follows:
- Each piece of debris swept out of the field is worth 2 points (each piece must completely cross the inside edge of the black border line).
- The robot gets 20 points for finding the treasure and signaling this fact with a noise.
- The robot gets 30 more points if it can pick up the treasure.
- The robot gets 60 points if it completes everything within 30 seconds, 50 points for 1 minute, 40 points for 1 minutes 30 seconds, and so on.

The debris as shown in Figure(3) consists of 25 black and gray gears found in Lego Mindstorms kits and the treasure is a statue composed of Lego girl and three transparent 1x2 bricks (red, yellow, green) and one 1x4 red brick and one 1x6 green brick found in Lego Mindstorms kits as shown in Figure(4).

There are some restrictions on the robot such as the robot must be made from parts found in a single Lego Mindstorms kit, but using plastic zip ties is allowed. The robot cannot be larger than 1 foot (30 cm) in any one dimension. The robot must be autonomous, with no remote control, and no interventions by hand are allowed during the playing time.

The competition saw six teams of four students each (not exclusively female) compete on May 14 at the Calgary Aerospace Museum at the IEEE Western Canadian Robot Games. Funding for the games was provided by IEEE. The Western Canada Robotics Society provided all the enthusiastic volunteers. There were other robotic competitions going on that day, including line-follower, sumo, and mine-sweeping robots. Guest speakers invited from universities talking about their exciting research in robotics. Some commercial robotics companies demoed their wares, including humanoid robots. Large video screens and audio allowed everyone to see the details of every competition, even if they were not immediately adjacent to a particular competition table. See www.robotgames.com for more information.

For the Lego Treasure Hunt, we had two categories, one for the younger students (grade 5 and under) and one for the older (grades 6-8). We had 6 teams competing, and first, second, and third prizes (personalized plaques) were awarded.

Only some of the robots were programmed to detect the Lego girl “Treasure” and try to avoid her. However, even these robots were not consistent at avoiding her, and usually she...
was knocked over. No robots were programmed to try and pick up the robot girl. We asked the students why they didn’t build a robot that simply knocked the girl over onto a “dust pan”. The students all replied that their teachers had told them that would be cheating because it wouldn’t be “picking up”. From this, we learned that engineering design can be a foreign concept to teachers who are very focused on rule-based tasks, rather than goal-oriented tasks. In the next phase of the program we plan to be more specific that creative design solutions will be rewarded, as long as they don’t clearly violate a specific regulation.

The girls all appeared to be having a great time, not only competing in their own event but also in soaking up the atmosphere of robotics enthusiasm. The teachers who accompanied the students confirmed that the students had great time, learned a lot, and both teachers and students expressed the desire to keep the program running the following year.

### 4 Results

In order to gage the effectiveness of the program we provided surveys to the teachers, who administered them to the students after obtaining parental permission. We twice administered the survey, once in October and once in May (after the robot games). In the October survey we had 24 girls from three schools surveyed, including 3 in grade 4, 1 in grade 5, 18 in grade 6, and 2 in grade 7. In the second survey we had 14 girls remaining in the program, who all participated in the robot games.

In both instances, the following survey questions were asked:

1. I think female engineers are geeks or cool.
2. I think girls can build/design things just as well as boys.
3. I think that technology is harmful or beneficial to the world.
4. Before participating in this robotics project, had you though about a career as an engineer?
5. How often have you been involved in an engineering project before this one?
6. How much did you know about robotics before you started working with this program?
7. After participating in this robotics project, do you think that you would consider a career as an engineer?
8. How much do you think you learned about of robotics increased as a result of this program?
9. What difference do you think having an engineer as a teacher made?

Looking at basic attitudes, in the 1st survey 80% of girls already started with an evaluation of ‘cool’ for female engineers, and only 8% with ‘geek’ (Figure 7). This was a much more positive attitude than we expected to see at first. The 2nd survey indicated better attitudes, with an additional 13% considering ‘cool’ and none thinking ‘geek’. In both 1st and 2nd surveys the answers to question 2 (girls designing as well as boys) was over 90% (Figure 8).

Many efforts to recruit women into STEM careers focus (often exclusively) on highlighting societal benefits, under the assumption that women often choose careers based on how they see it “helping” the world (an assumption which has some support in the literature, for example [9]). Comparing the 1st and 2nd survey results, the number of girls that answered technology is beneficial went from 50% to 73%, but also the number that said it was harmful went up from 4% to 13% (Figure 9). This is fairly remarkable considering the particular student project had no obvious societal benefit, and were not told of any possible applications of the ideas to society. Since the number that said it was harmful also went up, it may simply be that more students felt they knew enough to have an opinion on the matter after the program.

For the rest of the survey results, the results of 1st and 2nd surveys are combined. Surprisingly, 60% of the girls had felt they had been involved with “engineering” projects before (Figure 10). Only 45% felt that having an engineer as a teacher (the graduate student mentor involved in the project) made ‘a lot’ of difference, and 22% felt it made no difference at all (Figure 11). From these statements, we infer the girls may have a somewhat sophisticated self-image of themselves when it comes to technology. Thus, selling this particular group of girls on STEM careers may be easier than we thought before starting the program.

For robotics specifically, 79% said they did not know anything about robotics before the program, and 18% claimed they know ‘a lot’ (Figure 12). This 18% had been involved with Lego robots before in their school. We had 55% who thought they learned about robots from the program, yet 26% said they hadn’t (Figure 13). The high negative
responses here are not explained by the fact that stem from the 24 students who answered this survey only a month into the program, since students at the end answered ‘no’ at a 21% rate. It is most likely explained by the fact this project was presented as a ‘fun’ project without traditional learning evaluations.

Before starting the program, 55% of girls responded they had thought about a career as an engineer (Figure 14). This may seem like a high number, but Calgary does have a large proportion on engineers in the city and girls will know family members who are engineers. In fact, the Schulich School of Engineering at the University of Calgary has the highest female proportion of engineers in the country at 25%, and one of the main reasons given for this is the large number of women who have engineers as fathers in Calgary. Our project increased this number to 74%, and decreased the number who said ‘no’ from 32% to 8% (Figure 15). Based on the goals of this project, the responses to these questions verify that our project was a success: we interested girls in STEM careers.

We made assumptions about the girls that they wouldn’t be enthusiastic or knowledgeable about engineering or robotics beforehand, and that our program would have to sell them and teach them. We found that girls started with positive images of engineering and thought that they already had technical knowledge. Our survey results seem to indicate that the program was successful in improving attitudes even further.

5 Acknowledgments

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6 Conclusions

Our program to interest girls in STEM careers relied on a female engineer mentor who guided the girls through the design of a robot for a fun competition over an eight month period. Based on oral feedback from the girls and their teachers, the program was greeted
with great enthusiasm and we have been invited back to continue the program the next year. Our survey results verify that girl’s attitudes toward engineering careers indeed improved as a result of the program.

References


Figure 14: Before participating in this robotics project, had you thought about a career as an engineer

Figure 15: After participating in this robotics project, had you thought about a career as an engineer