Motivation Factors for Middle and High School Students in Summer Robotics Program (Fundamental)

Dr. Michele Miller, Campbell University

In 2017, Dr. Michele Miller joined Campbell University as a Professor and Associate Dean in their new School of Engineering. Prior to that, she was a professor of mechanical engineering at Michigan Technological University where she did research on precision grinding, micro sensors, and engineering education. She received a PhD from North Carolina State University in mechanical engineering.

Dr. Nina Mahmoudian, Michigan Technological University

Dr. Nina Mahmoudian is an assistant professor in the Mechanical Engineering-Engineering Mechanics Department at Michigan Technological University since 2011. She is the founding director of the Nonlinear and Autonomous Systems Laboratory (NASLab). Her research interests include robotics, dynamics and control of autonomous systems, and energy autonomy. She is a recipient of 2015 National Science Foundation CAREER award and 2015 Office of Naval Research YIP award.

Ms. Saeedeh Ziaeefard, Michigan Technological University

Saeedeh Ziaeefard is a PhD student and research assistant with Nonlinear and Autonomous Systems Laboratory (NASLab) in the Department of Mechanical Engineering-Engineering Mechanics at Michigan Technological University. Her research interests include engineering education, control and navigation of autonomous underwater vehicles.

Dr. Mo Rastgaar, Michigan Tech

Mo Rastgaar received the Ph.D. degree in mechanical engineering from Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, in 2008. He is currently an Associate Professor in mechanical engineering and the Director of the Human-Interactive Robotics Lab. His present research focuses on assistive robots by characterizing the agility in the human gait. Dr. Rastgaar is a recipient of 2014 NSF CAREER Award.

Micah R. Koller, Michigan Technological University

Motivation Factors for Middle and High School Students in Summer Robotics Program (Fundamental Research)

Introduction

Robotics provides an opportunity to engage more students in STEM. Veltman, et al. [1] and Chubin, et al. [2] observe that robotics is particularly effective in attracting male student interest. Many current robotics programs are mission-based. That is, students build robots that are strong or fast to carry out a mission in competition with other robots. Several researchers have shown that female students are often less motivated by competitive, mission based approaches [3-5]. In our own rural area, females are less likely (1 girl:10 boys) to participate in robotics programs, which mirrors national trends [6]. Female students are more likely to be motivated by interactions with people and design applications that help others [3,7-8]. Evidence suggests that for female students with an interest in science and engineering, there needs to be a meaningful context for nurturing that interest into sustained motivation for exploring career paths, especially in a male dominated field such as mechanical engineering [1].

We are developing robotics programs that provide context where students can envision using robots to solve problems and to help people. The implementation of these programs provides an opportunity to learn more about student interests and motivation. This paper explores the following research questions:

- What factors affect student interest in robotics?
- Do the factors differ by gender and grade level?

Description of Summer Robotics Programs

Our laboratory for exploring these questions is a summer youth program in robotics at Michigan Technological University. In summer 2015, we offered two week-long robotics camps. The Women in Engineering (WIE) camp familiarized high school girls with multiple engineering disciplines, and girls could choose robotics as one of their content modules for the week. The Summer Youth Program (SYP) called "Robotics: Manipulators and Underwater Monitoring" was a week-long camp for 6^{th}-8^{th} graders and devoted solely to robotics. In summer 2016, we offered the same two camps and added two more: the Exceptional Scholars Program (ESP) that has a similar structure to WIE but is open to boys and girls and a second week of SYP for girls only. All the camps are advertised to schools in the local area and across the university network of alumni and supporters. For the WIE, ESP, and girls-only SYP, students received scholarships to attend.

The robotics camps make use of two platforms: an underwater glider called GUPPIE and a surface electromyography (sEMG)-controlled manipulator called Neupulator. GUPPIE is an underwater robot that has application in monitoring and inspection of the environment, thus introducing the concept of robots as co-explorers in everyday life. Neupulator is a human-interactive robot that uses electrical activity of human muscles to move a manipulator. It

introduces students to assistive robots, which are a class of co-robots that amplify or compensate for human capabilities.

Figure 1 outlines the camp week's activities that include design, programming, production, assembly, and test and validation. The SYP groups spend full days with us while the WIE and ESP groups spend half-days (spending the rest of the day on other engineering activities). For Days 1 and 2, sessions take place in one large group as students gain general knowledge about robotics, engineering process, engineering design, and programming. The WIE and ESP groups spend less time on each component and do fewer mini-projects than the SYP groups. In Days 3-5, students experience production, assembly, and testing of the GUPPIE and Neupulator robots. For Days 3-5, students work in two smaller groups. For SYP, one group attends the GUPPIE sessions in the morning and Neupulator sessions in the afternoon. The other group attends the sessions in reverse. For WIE and ESP, one group works on Guppie only, and one group works on Neupulator only. Each student receives a package containing electrical and mechanical components, instructional materials, activity worksheets, and extra papers for taking notes. Refer to [9] for more details about the week-long curriculum.

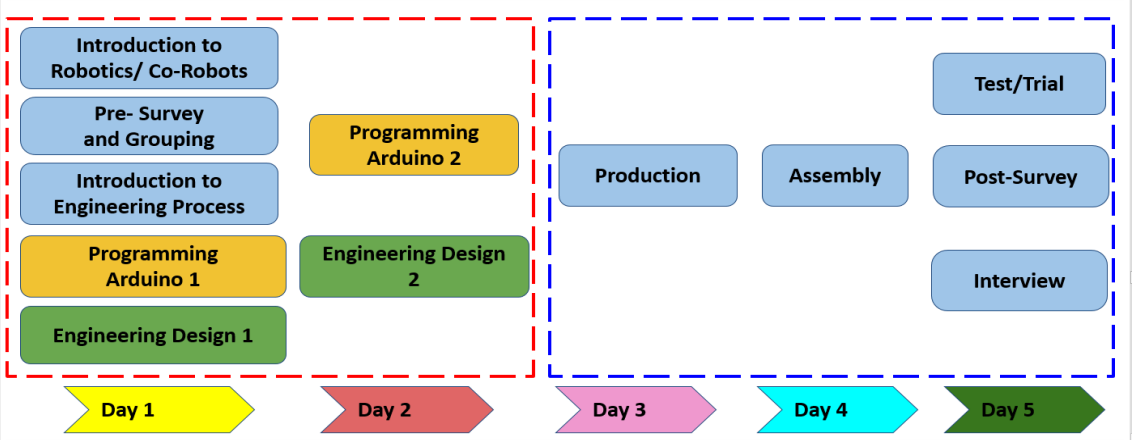

Figure 1. Schedule for week-long robotics camps

Methods

We collected several forms of data during each week. Students completed a pre-camp survey on Monday morning and a post-camp survey on Friday afternoon. The pre-camp survey asked about hobbies, career interests, and prior experience with robots and computers. Both pre and post-camp surveys asked students to rate their interest in a variety of STEM activities. The post-camp survey also asked for an evaluation and suggestions to improve the program. In addition to these surveys, in 2016, students completed multiple short activity surveys during the week. Students would rate the activity they just did and select reasons for their ratings from a prescribed list. Other forms of data collection included observations, work products, and end-of-week group interviews. Addressing the research questions in this paper relies primarily on the survey data. We looked at correlations between robotics interest rating and other survey responses. We broke the data into four groups: high school girls, high school boys, middle school girls, and middle school boys. Table 1 summarizes the number of students from these groups in the robotics camps in 2015 and 2016. Our analyses looked at differences amongst these

four groups. We also looked at differences between high schoolers and middle schoolers and between girls and boys.

Table 1. Number of participants in each week-long robotics camp

	HS Girls	HS Boys	MS Girls	MS Boys
2015 WIE	26			
2015 SYP			2	18
2016 WIE	26			
2016 ESP	5	21		
2016 SYP1				20
2016 SYP2			11	

Results and Discussion

Robotics Interest In pre and post-camp surveys, we asked students to rate their interest in robotics and other topics on a 1-7 scale with 7 being the highest. Figure 2 summarizes the averages for this rating for the students who completed both pre and post-camp surveys. The boys tend to have a higher interest in robotics than girls, and the middle schooler interest is higher than the high schoolers. A t-test shows that the difference between the middle and high schoolers is significant both pre (p=0.012) and post (p=0.006). This makes sense as the middle schoolers signed up for a robotics camp whereas the high schoolers signed up for an engineering camp in which robotics was just one component. A comparison of all the boys as a group with all the girls reveals a difference in the pre-camp (p=0.03) but not the post-camp survey. It is not necessarily true that girls responded more positively to the program than boys because when ratings start out higher (as they do for the boys), there is less room for them to increase. Finally, in both the pre and post-camp surveys, t-tests show no statistically significant difference in interest between boys and girls in the same age group.

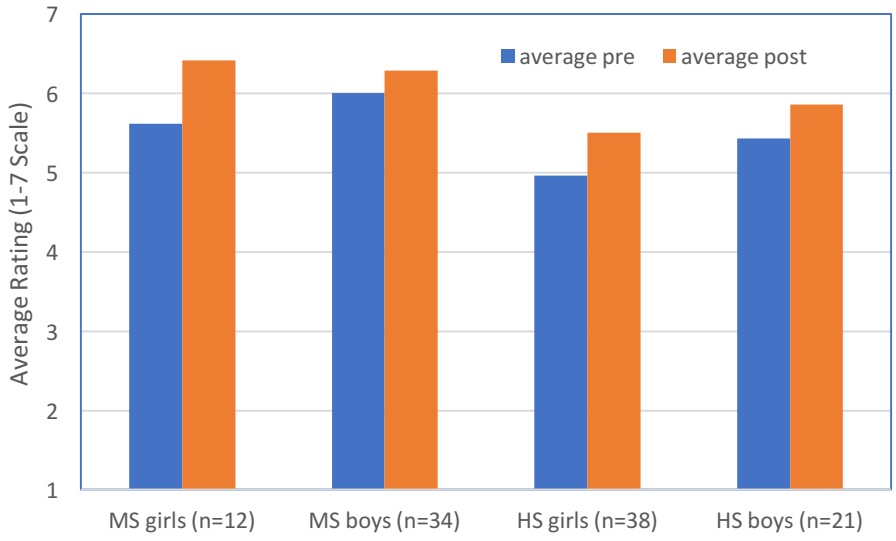

Figure 2. Comparison of pre and post-camp ratings of robotics interest

Predicting Interest in Robotics To identify factors that might contribute to robotics interest, we looked at correlations between the robotics interest rating and the following factors:

- Age (middle or high schooler)
- Gender
- Computer interest (1-7 scale)
- Computer programming interest (1-7 scale)
- Design and making things interest (1-7 scale)
- Science interest (1-7 scale)
- Math interest (1-7 scale)
- Friends who do robotics (1-5 scale from strongly disagree to strongly agree)
- Family members who do robotics (1-5 scale from strongly disagree to strongly agree)
- Prior robotics experience (1-3 point scale from no experience to extensive experience)

Based on the pre-camp surveys, robotics interest correlated ($p<0.05$) most strongly with (in descending order):

1. Prior robotics experience
2. Interest in computer programming
3. Interest in computers
4. Family members who do robotics
5. Interest in designing and making things
6. Friends who do robotics

Based on the post-camp surveys, robotics interest correlated ($p<0.05$) most strongly with:

1. Interest in computer programming
2. Interest in computers
3. Interest in designing and making things

From pre to post, the prior experience, friend influence, and family influence disappear. That is an encouraging shift as those may be factors that cannot be changed.

Motivations for Robotics Interest In 2016, after students rated their level of interest in robotics, they were also asked to rate their level of agreement with the following potential reasons for their interest:

- I'm good at robotics (abbreviated below as *Good at it*)
- My friends and family encourage my interest (*Friends/family*)
- I love robotics (*Love it*)
- Robotics is useful to my career goals (*Useful*)
- I have lots of ideas for useful things to do with robots (*Ideas*)

Their level of agreement was on a four-point scale of Strongly Agree, Agree, Disagree, and Strongly Disagree. Not a factor was also a choice. Table 2 summarizes the correlations between the robotics interest ratings and the reasons. Note that *Love it* is a strong reason for all groups in both the pre and post-camp surveys. In the pre-camp survey, the high schoolers differ from the middle schoolers in that *Useful* and *Ideas* correlate with interest. Also in the pre-camp survey, *Good at it* correlates with interest for boys but not for girls. In the post survey, *Friends/family* comes up for most groups; perhaps that means that participants made friends during the week. Also, in the post survey, *Good at it* came up for both boys and girls—a positive outcome!

Table 2. Correlations between robotics interest and reasons, ordered from highest to lowest correlation coefficient

	Correlating Reasons from Pre-Camp Survey ($p<0.05$)	**Correlating Reasons from Post-Camp Survey ($p<0.05$)**
All Girls	Love it, Useful, Ideas, Friends/family	Love it, Good at it, Useful, Friends/Family, Ideas
All Boys	Love it, Good at it, Useful, Ideas	Love it, Good at it, Useful, Friends/Family
All HS	Love it, Useful, Ideas, Good at it	Love it, Useful, Good at it, Friends/family, Ideas
All MS	Good at it, Love it	Love it, Good at it, Friends/family, Useful
HS Girls	Love it, Useful, Ideas	Love it, Useful, Good at it, Friends/family
MS Girls	Love it, Friends/Family	Love it
HS Boys	Love it, Good at it, Useful, Ideas	Useful, Love it, Good at it, Ideas
MS Boys	Good at it, Love it	Love it, Good at it, Friends/family

We also asked participants about their hobbies and the reasons they liked their favorite hobby. They selected from a list of reasons (shown on the *x*-axis in Figure 3) and could select more than one. They reported a wide variety of hobbies spanning from sports to artistic pursuits to robotics. Figure 3 compares the data for the four groups of students. For all groups, the top reason for a hobby being their favorite was *It's fun*. Comparing the responses of all girls and all boys in Figure 4, the girls were more likely to give *It's interesting* as a reason while the boys were more likely to give *I'm good at it* as a reason. Comparing the high and middle schoolers in Figure 5, the high schoolers were more likely to give *It's useful* and *I can do it with other people* as reasons. When trying to create STEM activities that students would want to do informally in their spare time, it is helpful to keep in mind the reasons they do their hobbies.

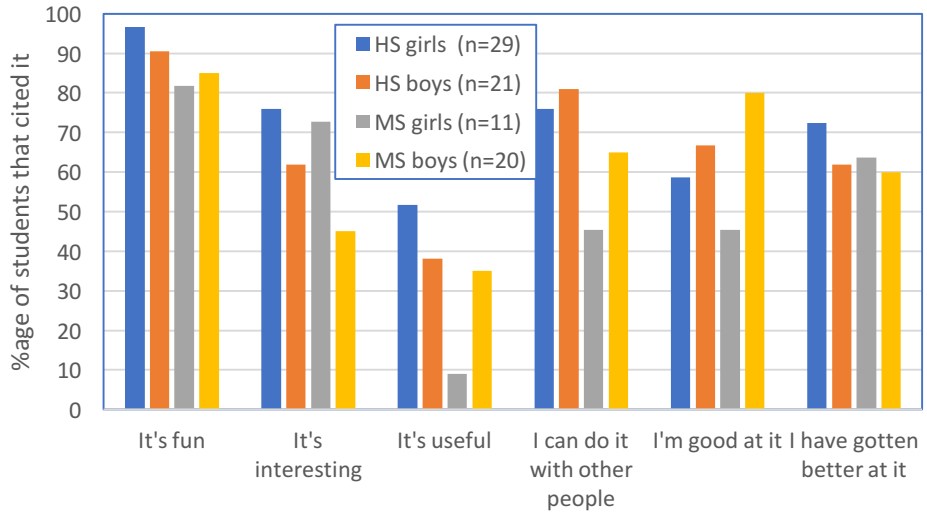

Figure 3. Reasons that students give for a hobby being their favorite

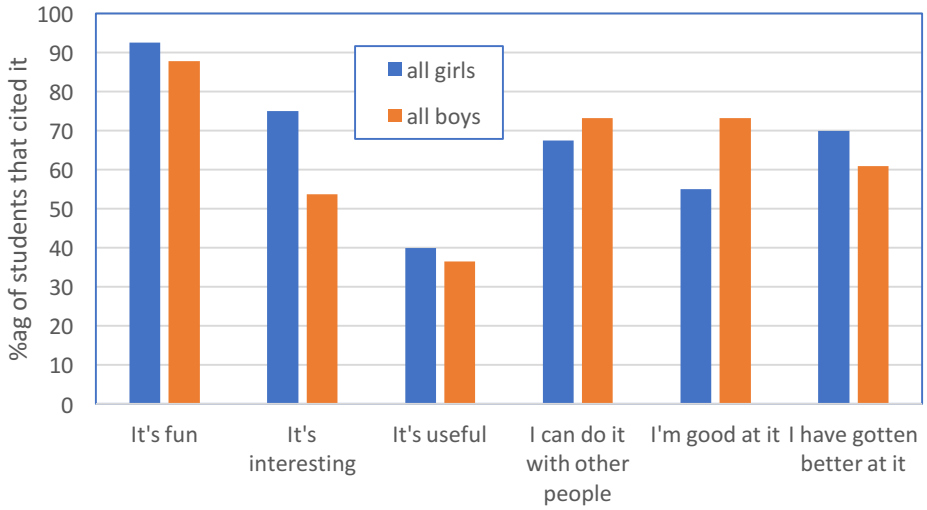

Figure 4. Comparison of girls' and boys' reasons for their favorite hobby

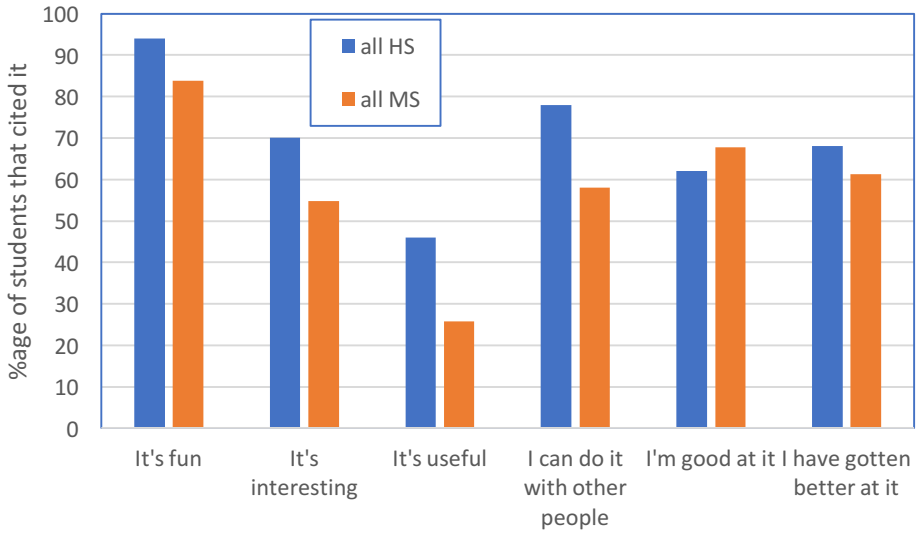

Figure 5. Comparison of high schoolers' and middle schoolers' reasons for their favorite hobby

Ratings of Specific Robotics Activities In the 2016 camps, we administered short surveys after each major activity for two purposes. The first was for formative feedback that we could use to improve the modules. The second was to obtain more specific information about student interests. The surveys took less than a minute to complete. They asked students to rate the activity they just did on a scale of 1-7, to check reasons for their ratings, and to rate their confidence on a scale of 1-7 at the beginning and end of the activity. Table 3 lists the sessions for the middle school camps where an activity survey was given.

Table 3. Syllabus for middle school week-long camp

Session	**Activity**
Monday Morning	Introduction to Robotics and Arduino Programming
Monday Afternoon	Introduction to CAD, Designing a Robotic Arm
Tuesday Morning	Arduino Projects
Tuesday Afternoon	Project involving building and Arduino programming
Wed. Guppie	Partial assembly and wiring of Guppie
Wed. Neupulator	Assembly and wiring of the Neupulator arm, motors, and power supply
Thurs. Guppie	Final assembly and programming of Guppie
Thurs. Neupulator	Wire and integrate the muscle sensors to the Neupulator arm
Friday Guppie	Testing
Friday Neupulator	Program and test the Neupulator

Figure 6 summarizes the ratings for the middle school girls and boys and shows that the ratings are fairly consistent between the boys and girls. For example, both groups gave high ratings to Monday and Tuesday mornings and low ratings to Monday and Tuesday afternoons. The Monday afternoon session involved using CAD design software while the Tuesday afternoon activity involved Arduino programming. The "reasons" portion of the activity survey provides some explanation for the low ratings. For Monday afternoon, 43% of the students indicated *It*

was frustrating, and 37% indicated *I didn't know what I was doing*. For Tuesday afternoon, 48% indicated *It was frustrating*, and 39% indicated *I didn't know what I was doing*. In follow-up interviews, several students re-iterated their frustration when learning CAD and Arduino programming, but with more practice, their view of these activities improved later in the week. Notably, the ratings were higher for the girls for the Wednesday Neupulator and Thursday Guppie sessions. These sessions involved hands-on building with teammates. Both the boys and girls expressed few negative reasons. The girls, however, expressed more positive ones. In particular, for those two sessions, they cited the following reasons more frequently than the boys: *It was useful*, *I can do it with other people,* and *I have gotten a lot better at it*.

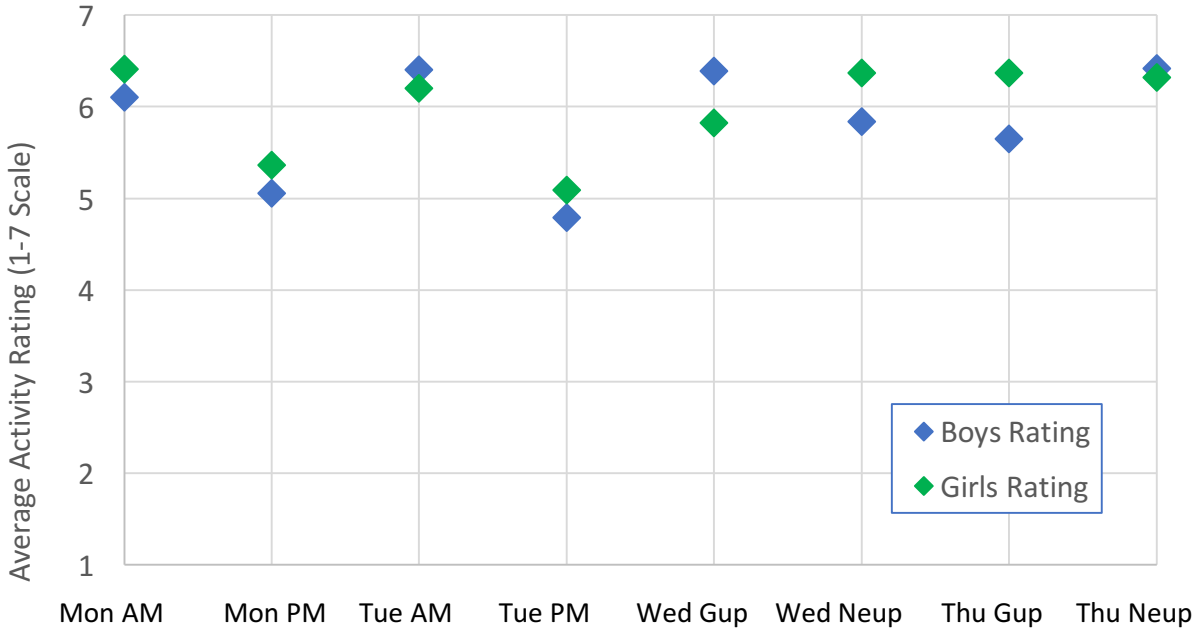

Figure 6. Average activity ratings for the middle school boys and girls

Figure 7 summarizes the activity ratings for the high school boys and girls. The highest ratings occur at the end of the week when students test their robots. The girls rated the Wednesday Guppie session much lower than the boys. To understand why, we looked at the "reasons" data. It showed that 54% of girls and 8% of boys indicated *It was frustrating*, 46% of girls and 0% of boys indicated *I didn't know what I was doing*, and 38% of girls and 15% of boys indicated *I didn't have the background for it*. Note that most of the high school girls participated in the WIE session, and all the high school boys participated in ESP which came two weeks later. It is likely that the ESP group benefited from lessons learned by the instructors during WIE.

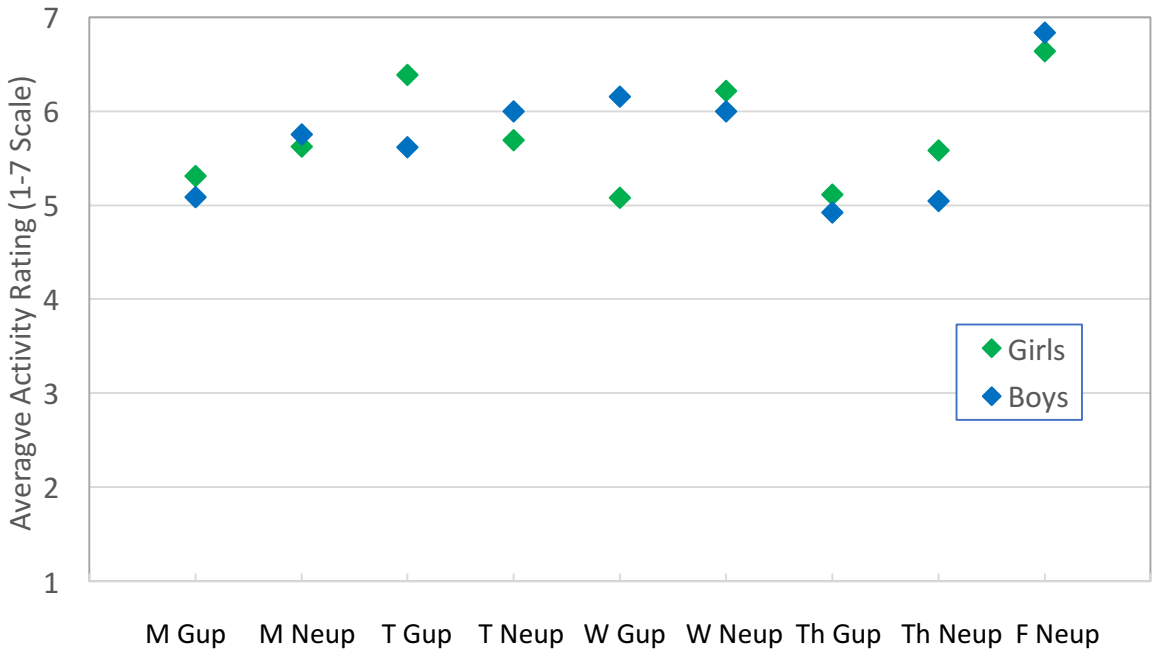

Figure 7. Average activity ratings for the high school boys and girls

Figure 8 summarizes the reasons portion of the activity surveys for all four groups in 2016. It combines the ratings for all activities during the week. It shows that frustration, not having the background, and not knowing what I was doing were the reasons most cited to explain lower ratings. These reasons occurred more frequently for the high school students. An explanation is that the high schooler's time for completing activities was shorter than for the middle school students. The WIE and ESP format included non-robotics sessions as well. The reasons cited most often to explain positive ratings were: *It was interesting*, *It was fun*, and *I learned a lot*. The graph suggests a few differences amongst the groups. The girls indicated *It was fun* more often than the boys. The middle school boys differed from the other three groups in that they less often indicated *It was interesting*, *It was useful*, and *I learned a lot*.

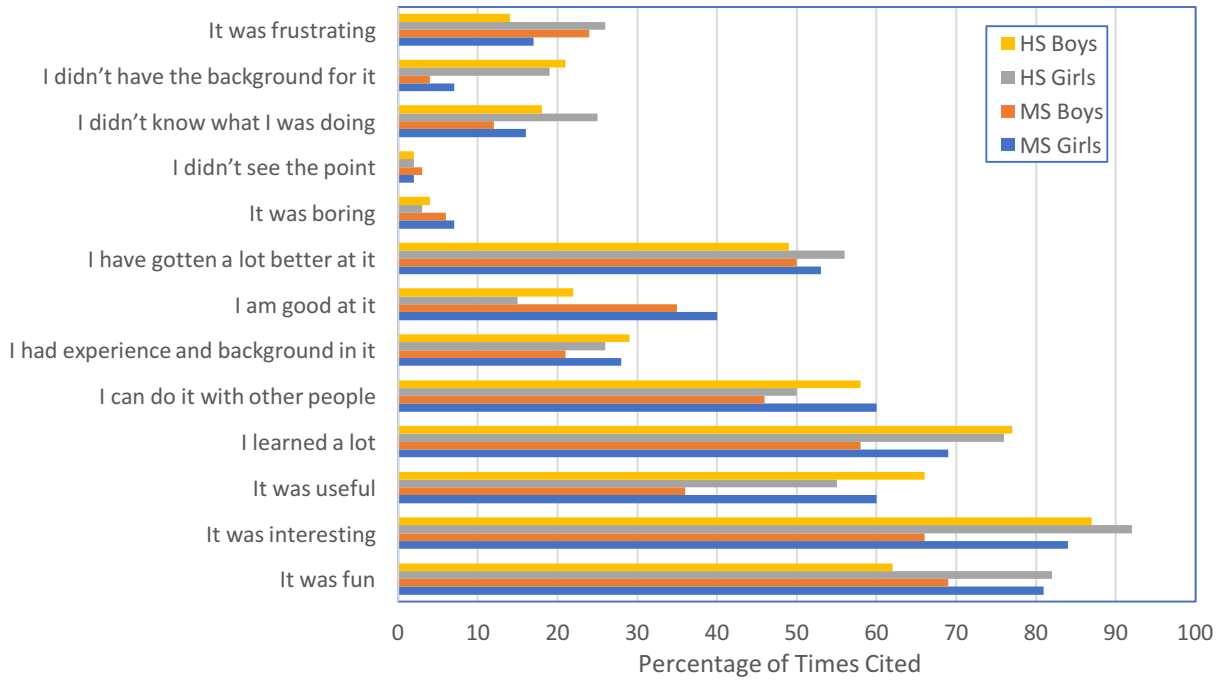

Figure 8. Frequency of reasons given to explain an activity rating

We looked at correlations between the activity ratings and the reasons. Tables 4 and 5 show the correlating reasons with $p<0.05$ in order of correlation coefficient. For all four groups, *It was fun* correlated most strongly to the rating of the activity. For middle school girls, negative reasons (*I didn't know what I was doing*, etc.) explained more of the variation in ratings than positive ones. To look at this further, we grouped all the positive reasons into one factor and all the negative reasons into one factor. For middle school boys, the correlation coefficient for the robotics rating with the positive reasons factor was 0.73, and the correlation coefficient for the robotics rating with the negative reasons factor was -0.78. For the middle school girls, the same two correlation coefficients were 0.55 and -0.76, respectively. One final observation is that *I am good at it* was a more important factor for the boys than it was for girls (both MS and HS).

Table 4. Top reasons that correlate with a robotics activity rating for the middle school students

MS Girls	MS Boys
It was fun	It was fun
I didn't know what I was doing	It was interesting
I didn't have the background for it	I didn't know what I was doing
It was frustrating	It was frustrating
It was boring	It was boring
I didn't see the point	I learned a lot
It was useful	I am good at it
I have gotten a lot better at it	I can do it with other people
I am good at it	I didn't have the background for it
I had experience and background in it	I have gotten a lot better at it
It was interesting	It was useful
I learned a lot	I didn't see the point
	I had experience and background in it

Table 5. Top reasons that correlate with a robotics activity rating for the high school students

HS Girls	HS Boys
It was fun	It was fun
It was frustrating	It was interesting
I didn't know what I was doing	It was frustrating
It was useful	I learned a lot
I have gotten a lot better at it	It was boring
It was boring	I am good at it
It was interesting	I didn't know what I was doing
I had experience and background in it	I can do it with other people
I didn't have the background for it	It was useful
I can do it with other people	I didn't have the background for it
I learned a lot	I had experience and background in it
I didn't see the point	I have gotten a lot better at it
I am good at it	

Student Confidence For the middle school programs, we added questions to the daily activity survey about confidence. At the beginning and end of each block of activity, students rated their confidence on a scale of 1-7. Figure 9 summarizes the average results for 20 middle school boys and 11 middle school girls. Note that the boys and girls attended the robotics program in different weeks—these sessions were not coed. For both groups the confidence increases from the beginning to the end of each activity. Also, for both groups, the beginning confidence grows as the week goes on. Early in the week the beginning confidence for the girls is lower than the boys, but by the end of the week, it is the same. For the whole week, the girls and boys have about the same ending confidence.

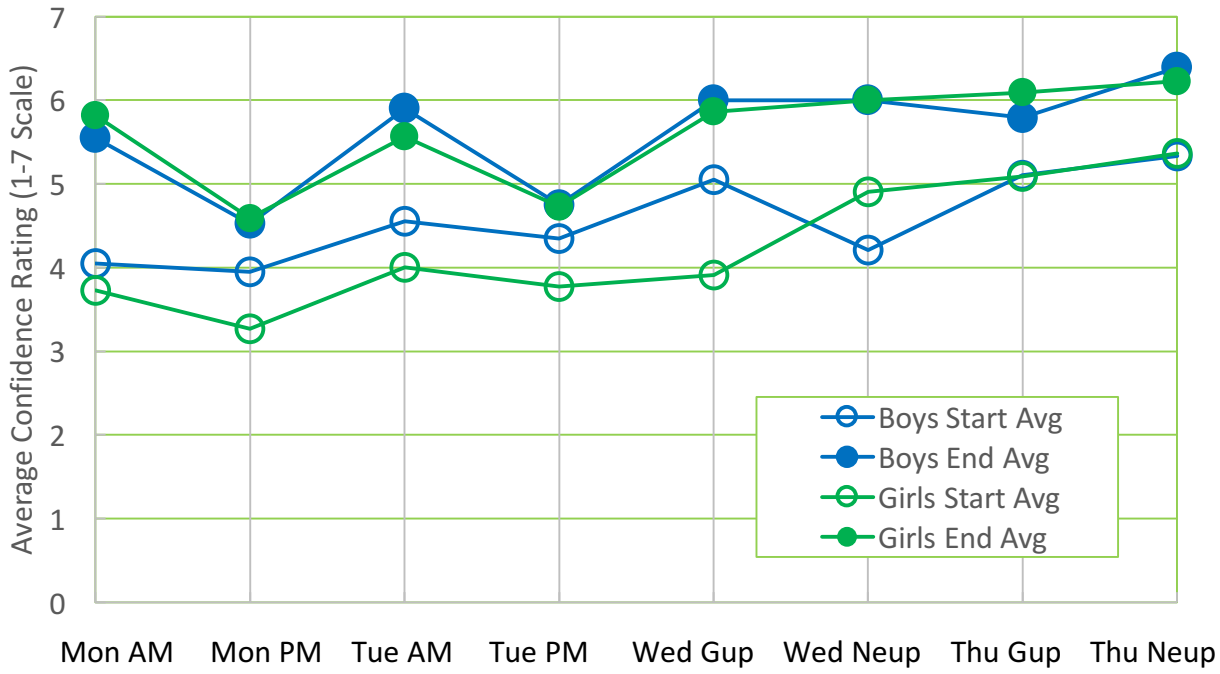

Figure 9. Confidence of middle schoolers at the beginning and end of each activity

Summary of Findings

This paper looked at: changes in robotics interest pre to post camp, factors that may predict robotics interest, motivations for robotics interest, and motivations for hobbies. Taking the data collection to a more granular level, the paper also looked at: ratings for specific robotics activities, motivation factors for specific activities, and pre to post changes in confidence in doing the activities.

Participating in the robotics camp had a positive effect for both boys and girls. Whereas boys had higher interest in robotics than girls pre-camp, by post-camp there was no statistically significant difference. Pre-camp, the factors that were the strongest predictors of robotics interest were prior robotics experience, interest in computer programming and interest in computers. Post-camp, interest in designing and making things replaced prior robotics experience in the top three. The motivations for robotics interest showed some differences amongst the four groups (HS girls, HS boys, MS girls, MS boys) in the pre- and post-camp surveys. *Love it* was a reason for robotics interest for all four groups both pre and post. *Useful* was a reason both pre and post for HS girls and boys but not MS girls and boys. *Good at it* was a reason for all the groups except MS girls. The analysis of motivations for hobbies also showed the MS girls to differ from the other three groups. They were less likely to indicate *It's useful*, *I can do it with other people*, and *I'm good at it* as reasons they liked their favorite hobby.

In terms of the various kinds of activities that go into doing robotics, most students preferred the highly hands-on activities of fabricating, wiring, and assembling. They found these sessions to be fun. Using unfamiliar software or doing programming were the lowest rated activities as students often felt frustrated or that they didn't know what they were doing. All groups of

students indicated many more positive motivation factors than negative ones in the daily surveys. And the ratings for all activities tended to be high. Even so, correlations between the ratings and motivation factors indicated that *both* the positive and negative factors have significant effects on the ratings. The analysis of the MS girls and boys revealed an interesting difference. For the boys, the effects of the positive and negative factors were balanced (correlation coefficients of 0.73 and -0.78). For the girls, the negative factors had more of an influence than the positive ones (correlation coefficients of 0.55 and -0.76). The pre and post activity confidence data also showed different trends for the middle school boys and girls. While the girls' pre-activity confidence lagged the boys' early in the week, it caught up with the boys by the end of the week. The post-activity confidence between the groups was similar for the whole week.

Implications for Designing Robotics Programs

Our project has thus far involved a fairly small number of students. More data needs to be collected to draw firmer conclusions. Nevertheless, the results lead to some suggestions for delivering robotics programs that engage both boys and girls. The first suggestion is to collect formative data about individual robotics activities. The post-activity survey takes very little time, but provides useful information. Students rated some types of robotics activities much more highly than others. For low rated activities, it was helpful to have their reasons (*It was frustrating*, etc.). For negatively rated activities, boredom was rarely the problem. Instead, the activity was too challenging given the students' level of knowledge at that time. Care needs to be taken to provide the appropriate level of challenge. This is particularly important for engaging middle school girls. Our data suggested that their ratings of robotics activities were correlated more with negative reasons than positive ones. (In contrast, for middle school boys, the strength of correlations was about the same for the positive and negative reasons.) A final suggestion is to distribute highly rated activities throughout the week. Frustration is part of learning and cannot be eliminated entirely. Activities, such as building, that are dependably fun should occur multiple times.

Acknowledgment

This work is supported by National Science Foundation under grant number 1426989.

References

1. Veltman, M., Davidson, V. and Deyell, B. (2012) "Richer Connections to Robotics through Project Personalization," *Advances in Engineering Education*, Summer 2012.
2. Chubin, D., Donaldson, K., Olds, B. and Fleming, L. (2008) "Educating Generation Net--Can U.S. Engineering Woo and Win the Competition for Talent," *Journal of Engineering Education*, Vol. 97, No. 3, pp. 246-257.
3. Tavrou, S., Thong, C., & Steele, C. (2011) Increased female participation into engineering education through specialised courses, *Australasian*.
4. Matusovich, H.M., Streveler, R.A. and Miller, R.L. (2010) "Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values,"

Journal of Engineering Education, Vol. 99, No. 4, pp. 289-303.

5. Mattern, N., & Schau, C. (2002) "Gender differences in science attitude-achievement relationships over time among white middle-school students," *Journal of Research in Science Teaching,* Vol. 39, pp. 324-340.
6. Edmiston, G., "Designing Inclusive Curriculum: Engaging Girls with Science, Engineering and Technology using Robotics-A Literature Review," *Australian Council for Computers in Education Engineering Education*.
7. Eccles, J. (2007) "Where Are All the Women? Gender Differences in Participation in Physical Science and Engineering," *Why Aren't More Women in Science*, pp. 199-210.
8. Parikh S., Chen, H., Donaldson, K. and Sheppard, S. (2009) "Does Major Matter? A Look at What Motivates Engineering Students in Different Majors," *Proc. ASEE Annual Conference*, paper no. AC2009-1304.
9. Ziaeefard, S., N. Mahmoudian, M. Miller and M. Rastgaar (2016) "Engaging Students in STEM Learning through Co-Robotic Hands-On Activities (Evaluation)," *Proc. ASEE Annual Conference*, paper no. 15598.