



# ROBOTICS EDUCATION: APPLICATION AND OUTCOMES OF A SECONDARY SCHOOL GIRLS ROBOTICS SUMMER CAMP PROGRAM

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## ABSTRACT:

Robotics education for girls combines innately creative craft materials, standard robotics components, a bespoke programming environment, and professional development for teachers to create Secondary school classrooms that can benefit from flexible robotics intervention. The robotic program was put together to engage teenage girls from the underrepresented community; the Summer camp is an initiative that promotes the creation of collaborative expression-focused robots, locomotive robots, renewable robots like the wind turbine, feedback robots with sensors like the touch, light, ultrasonic and gyro sensors as opposed to more autonomous robots. In addition, competitive task-focused robot activities are frequently used. Botcamp emphasizes integration into conventional basic science classes such as basic science and essential technology to attract a wider audience. A larger student body than would be enrolled in electives Programs in technology and acquire interests in science and technology.

This paper discusses some classroom scenarios. initiatives, teamwork, problem solving, design thinking creativity. engineering education activities, such as hands-on knowledge of computer programming and prototyping, and the engineering design process. We present our outcomes grouped within three primary themes: first, in Technological Fluency, we present students' self-reporting of concepts learned, confidence with technology, and breaking of technology stereotypes; second, in Complementary Non-Technical Skills like communication and team work, we present other skills students learned by participating in the robotic camp program.

## INTRODUCTION:

The inventiveness and background of technology developers have a significant impact on the diversity of new technical breakthroughs. Given the underrepresentation of women and minorities in STEM fields, it is clear that society is not making full use of the innovative abilities and unique experiences that such underrepresented groups may provide. It is vital that students have pre-college experiences that allow them to practice engineering and help them build technology fluency in order to attract a larger range of students to pursue higher training and employment in engineering. Technological fluency is defined as the ability to manipulate technology creatively and for one's own benefit; an idea supported by our research [1] and others. [2] [3] [4] [5]. It is critical to provide opportunity for all students to achieve technical fluency; however, present pre-college engineering education practices usually limit interaction with engineering to a small group. Engineering-focused extracurriculars in secondary school frequently use high-intensity, contest-driven tasks as motivating hooks for students who thrive on competition [6] [7]. Engineering and technology subjects in secondary schools are typically provided as electives to students who already have an interest in engineering and technology. Unfortunately, present tactics are ineffective in reaching pupils who are uninspired by contests or who are uninterested in technology for its own purpose.

Our program, robotic education for young girls, aims to engage a more varied group of teenage girls in engineering practice, including those who are uninspired or uninterested in evolving technology initiatives. We want to do this through a robotics program that prioritizes expression and collaboration above competitiveness and provides a classroom environment for technology use. The camp robot hardware kit is intended to foster expressivity by integrating inherently creative and gender-neutral arts and crafts materials with regularly used robotics and technology components. We believe that via initiatives like the robotic camp, we can inspire different girls to participate in science and secondary school engineering instruction, thus making it possible to attract a more diverse population of girls to engineering careers.

The robotic program started in 2016 organized by the foundation with the goal of exploring the educational impact of expression-focused technology experiences for teenage girls. The robotic program initially began as an extracurricular intervention which aimed to diversify the Computer Science pipeline by engaging 11 to 19 year old girls [8] [9] [1]. At that time, others were also developing similar extracurricular programs for engaging young girls who were not interested in traditional robotics programs, STEM and competitions, by providing connections to robotics through creative topics like Renewable energy, motion and movements[10]. Following our initial implementation phase as an extracurricular program, we transformed the robotic program into a 1 week summer camp in order to increase participant self selection. By designing the robotic camp kit to enable craft based building followed by choreographic programming, we connected technological fluency to science education, which is well-regarded and supported in school systems and by students who may not have strong prior experience with electronics. We focused efforts on integration with non-technical, core courses in order to engage

students in engineering and programming practice who would otherwise avoid enrolling in a technical elective course or extracurricular activity.



Fig. 1. Student building robots, from left to right with the Lego mindstorm kit

The robotics camp hardware kit includes a large number of Lego Mindstorms, which is a hardware and software structure which develops programmable robots based on Lego building blocks. Each version includes computer Lego bricks, a set of modular sensors and motors, and Lego parts from the Technic line to create the mechanical systems. The system is controlled by the Lego bricks. While originally conceptualized and launched as a tool for supporting educational constructivism, Mindstorms has become the first home robotics kit available to a wide audience. It has developed a community of adult hobbyists and hackers following the product's launch in 1998. The LEGO MINDSTORMS EV3 set includes motors (2 large servo motor and 1 medium servo motor), sensors (2 touch sensors, ultrasonic sensor, color sensor, infrared sensor, and the new gyro sensor), the EV3 programmable brick, 550+ LEGO Technic elements and a remote control (the Infrared Beacon, which is only on Home/Retail mode). The EV3 can be controlled by smart-devices. It can boot an alternative operating system from a microSD card, which makes it possible to run ev3dev, a Debian-based operating system.

## **METHODS**

### ***A. Hypotheses***

We wish to understand the ways in which creative robotics activities within a disciplinary context impact student learning, and in particular, how student technological fluency is affected by this inclusive approach to technology exposure. Technological fluency itself is governed by two factors: student attitudes toward technology, and student technical knowledge. Each form of change is insufficient by itself in catalyzing a shift in the overall student-technology relationship. Empowered attitudes are required for students to apply knowledge. Knowledge is required for students to be effective in acting on their attitudes. Thus, we propose two specific hypotheses relating to enablers of student technological fluency:

1. The Robotics camp increases student and teenage girls' grounding of technical knowledge and technical skills.
2. The Robotics camp boosts young females' enthusiasm and confidence in using technology. Aside from fluency-centered hypotheses, a key aim for the robotic camp pilots arises from our desire to encourage all kids' technology. We believe that including robots into disciplinary core courses has the potential to draw a more varied young female population to technology and, as a result, to a route toward technological fluency. Our third hypothesis focuses on the kind of inclusivity attained through the robotic camp program[15]:
3. Robotics camp attracts a diverse range of participants, only female, with varying levels of technology experience [16].

If our evaluation supports these three hypotheses, we believe that robotic camp meets the need for an intervention that improves the technological fluency of a larger population of teenage girls through a different style of student engagement than the current pre-college engineering education status quo

### **B. Assessment Tools**

We divided the assessment of technological fluency into a major survey that reflected our hypotheses and a final competition that was held at the end of the camp: Student Knowledge with Regard to Technology (Knowledge). In order to investigate the widening demographics hypothesis, we also collected basic demographic information from students, such as race, age, and grade level. Pre and post questionnaires were given to students before and after their robotic camp project to measure student learning. Following the conclusion of their robotic camp project, a limited subset of 50 students were interviewed.

#### **1) Knowledge Survey**

Six short answer questions, nine multiple-choice hardware component questions worded as analogies, six multiple choice software questions, and ten multiple choice systems engineering questions comprise the Knowledge Survey. The short answer questions differed somewhat between the pre-test and post-test versions. The systems

engineering questions are taken from [13] and consist of ten items that describe the activities of devices and subsystems. The students were asked to determine whether each activity is a system "Input," "Output," or "Processing" (Table I). The outcomes of two short answer questions and two systems engineering questions are presented in this study. Multiple-choice questions in hardware and software are still being tested and developed.

TABLE I. MULTIPLE CHOICE QUESTION DETAILS

| Multiple Choice Questions   | Number Of Items | Answer Choices                |
|---|-----------------|-------------------------------|
| Systems Engineering Scale [13]:<br>Below is a list of actions. Check off whether each action is an input of information, the output of information, or the processing of information. | 10              | Input<br>Output<br>Processing |

### C. Demographics

In this paper, we present data and analysis from secondary school students experiencing their first robotic camp project. Data were collected from public secondary schools: five public secondary schools. Data were collected in 6 separate classes. These classes included all the secondary classes covering: Data were collected between 13th - 20th August . The number of students in the data samples were 50 because that was the number of students accepted into the summer robotics camp. Finally, our survey tools undergo regular refinement and modification of wording thus items that were introduced more recently may have fewer responses. The analysis in this paper excluded participants who did not meet the following two conditions: 1) were enrolled in a middle school class, and 2) were participating in their first robotic camp project.

There is Knowledge Survey data from 50 students in secondary schools . Of those, 40 students were from senior secondary and 10 from junior secondary school completed matching pre- and post- Knowledge Surveys.

### D. Analysis

Students were assigned unique subject numbers, and names were replaced by subject numbers throughout the data. The analysis methods used for the three types of survey items (short answer items, Likert-type attitudes items, and systems engineering items) are described below. *Short Answer Coding*: Open-ended questions were coded independently by two coders, each an expert in robotics. Survey responses were randomly assigned survey

ID numbers to make coding blind to student grade level and whether responses were from pre- or post- surveys, when possible. Responses could be assigned multiple codes if they expressed multiple unique ideas without overlap. The top response codes are provided in tables for the following four questions: “What was the best thing that you learned during the project?” (Table II), “Did you enjoy doing this project?” (Table III), “How did this experience change how you think about technology?” (Table IV), and “Should other students have this experience?” (Table V).

**Systems Engineering Scale:** For each of the 10 multiple choice questions, we assigned a score of 0 (incorrect) and 1(correct) for each participant's response. Each participant could then be assigned a systems engineering subscore on a scale from 0 to 10 representing the number of items he or she answered correctly. We then tested the hypothesis: the distribution of the student scores was different between the pretest and post-test. The score distribution had an asymmetrical distribution where the number of students achieving a maximum score on the evaluation prevented a normal distribution. This indicated that the appropriate statistical test for our hypothesis was a Wilcoxon Signed Ranks Test, a nonparametric test for comparing the median score of the Distributions. Through the data and analysis described, we identified two primary outcome themes: Technological Fluency and Complementary Non-technical Skills. Technological Fluency covers technical knowledge gains, confidence, and changes in technology stereotypes. Complementary Non-Technical Skills encompasses teamwork, perseverance, and several other personal skills. All student quotes included below are provided verbatim.

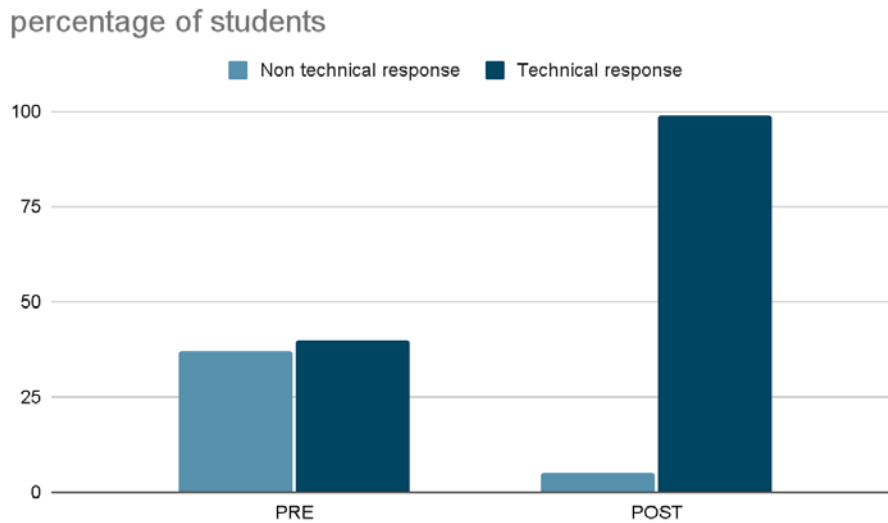
## **A. Technological Fluency**

### **1) Learning about Robotics**

As we hypothesized, students self-reported learning about robotics, technology, computers, programming, specific robotic components used in the class, and engineering design concepts across many different open-ended questions. For the following three open-ended questions, learning about technology was one of the top three most common student responses to each question. When asked “What was the best thing that you learned during the project?”, the majority of students described a technological learning gain. For example one student said “The best thing was just basically programming the lego car to move. When you tell something to do something and it works it feels amazing,”. When asked “Should other students have this experience?” said other students should because they would learn about technology mainly because their secondary school doesn't do enough on technology. When asked “Did you enjoy doing this project?”reported that they enjoyed the project because they learned about technology and social skills like teamwork. For example, a student said “YES! I didn't know much about robotics before this project. I definitely feel more educated about robotics now than I did before this project. It was a GREAT learning experience!”. In response to the question “How did this experience change how you think about technology?”, they reported that they learned something new about technology. For example, one student reported “I understand it much more now!!!”. These self-reported learning gains about specific and more

generalized technology knowledge and skills are supportive of the hypothesis “robotic camp increases student grounding of technical knowledge and technical skills and also social skills.” In addition to self-reported technical learning, an open ended knowledge question, designed to measure student understanding of robotic systems and components, indicated significant technical learning gains. Students watched a short video of a lego crafted wind turbine. After watching the video, they were asked “What parts did Daniel use to make the blades spin?”. Student short answer responses were coded as being: 0) video could not be played, 1) I don’t know, 2) a non-technical answer, 3) a conceptually correct technical answer but using incorrect terminology, or 4) a correct technical answer. Non-technical answers included craft materials, nonspecific technical parts (i.e. “robot parts”, “motors”), or structural parts not contributing to the robot’s function (i.e. “blades”). Correct technical answers included terms such as “medium motor”, “large motor”, “gears” and “pressure sensor”. Correct technical answers that were misspelled were coded as correct. A McNemar’s Test indicated there was a significant increase in the proportion (37.2% pre-, 95.5% post-) of students who gave a technical response, as shown in Fig. 2, to the question on the post survey,  $\chi^2(1) = 41.09$ ,  $n = 89$ ,  $p < .0001$ . This result supports the technical knowledge and skills hypothesis as these students demonstrated both increased knowledge of robot components and increased skill in describing a novel technological system.

Another part of the Knowledge Survey, the qualitative Systems Engineering Scale, measured significant learning gains between the pre- and post-surveys as shown in Fig. 3. A Wilcoxon Signed-ranks test indicated that the Systems Engineering knowledge subscore post-test (median = 8) was significantly improved over the Systems Engineering knowledge subscore pre-test (median = 7),  $Z = -4.820$ ,  $p < .0001$ ,  $r = .41$ ,  $n = 50$ . These increases indicate not only an improved understanding of robotics, but also improvements in student understanding of the systems engineering concepts of inputs, outputs, and processing. This finding of increased technology systems engineering further supports the knowledge and skills hypothesis. On two Likert-type responses related to learning technical knowledge, there were significant differences found between the pre- and post-surveys. On the statement, “I am curious about how robots work”, McNemar’s Test indicated there was a significant decrease in the proportion of students who agreed with the statement on the post-survey,  $\chi^2(1) = 4.84$ ,  $n = 108$ ,  $p = .043$ . In addition, a McNemar’s Test indicated there was a significant decrease in the proportion of students on the post survey who agreed with the statement “I would like to learn more about robotics”,  $\chi^2(1) = 7.2$ ,  $n = 108$ ,  $p = .012$ . At first glance, these decreases in curiosity seemed discouraging; however in combination with the measured and self-reported gains in knowledge with respect to technology, we hypothesize that for some students the project was adequate in fulfilling their desire for learning about technology. This interpretation indicates that future implementations may be improved by placing more emphasis on the expansive and growing field of robotics and introducing the robotic camp to students as a fragment of that field in order to seed new curiosity. In addition to this reported satisfaction of learning, we saw corresponding improvements in student confidence, described in more detail below.



**Fig. 2. Percent of students giving non-technical and technical responses on open-ended knowledge questions: “What parts did Daniel use to make the blades spin?”**

## 2) *Improved Confidence*

Given the self-reported and demonstrated learning improvements in technology and robotics, it is not unexpected that students' trust in technology increased as well. A McNemar's Test revealed a significant rise in the proportion of students who disagreed with the statement on the post-survey on the Confidence subscale Likert-type item, "I am not competent at constructing robots,"  $\chi^2(1) = 5.7, n = 50, p = .024$ . That is, the number of pupils who spoke up for their own ability in building robots grew. This interpretation is backed by data from a previous extracurricular robotics pilot, which likewise discovered an increase in student trust in robots [4], as well as short answer replies mentioned below. Students answering the question, "How did this experience change how you think about technology?", mentioned that they felt more confidence in their technology skills after the project. Some students noted increased confidence in programming, for example, "I've always assumed that technology was just too sophisticated for me to ever comprehend programming and how it works." "I now know that if I want to, I can learn fundamental programming abilities." "I always assumed technology was for dudes," stated another girl (7th grade female, technology education). "I now see that robotics is not just for males; I, too, can study it" (10th grade female, technology education). Other students gained confidence while working with the hardware, developing the structures of their robots, and presenting on their final projects. "I believe I became a lot better at understanding how to wire things up to the motors, and it taught me not to give up," (8th grade female, academic language arts).

Aside from increased confidence in certain technical abilities, the experience led to a transformation in identity with regard to technology for some pupils. One student, for example, stated that "using the robotic aspects helped me feel more connected and competent." It made technology feel more approachable rather than something only extremely brilliant people or nerds do" (8th grade female, accelerated language arts). This discovery of enhanced



technological confidence lends credence to the second hypothesis, "The robotics camp promotes student enthusiasm and confidence to engage with technology."

TABLE II. WHAT WAS THE BEST THING THAT YOU LEARNED DURING THE PROJECT? RESPONSE SUMMARY

| What was the best thing that you learned during the project? | Percent of Students<br>N = 50 |
|--|-------------------------------|
| Technical Learning   | 70.8%                         |
| Teamwork (positive indication)                               | 65.3%                         |
| Multidisciplinary Integration                                | 40.5%                         |
| Confidence and boldness to speak up                          | 70.89%                        |

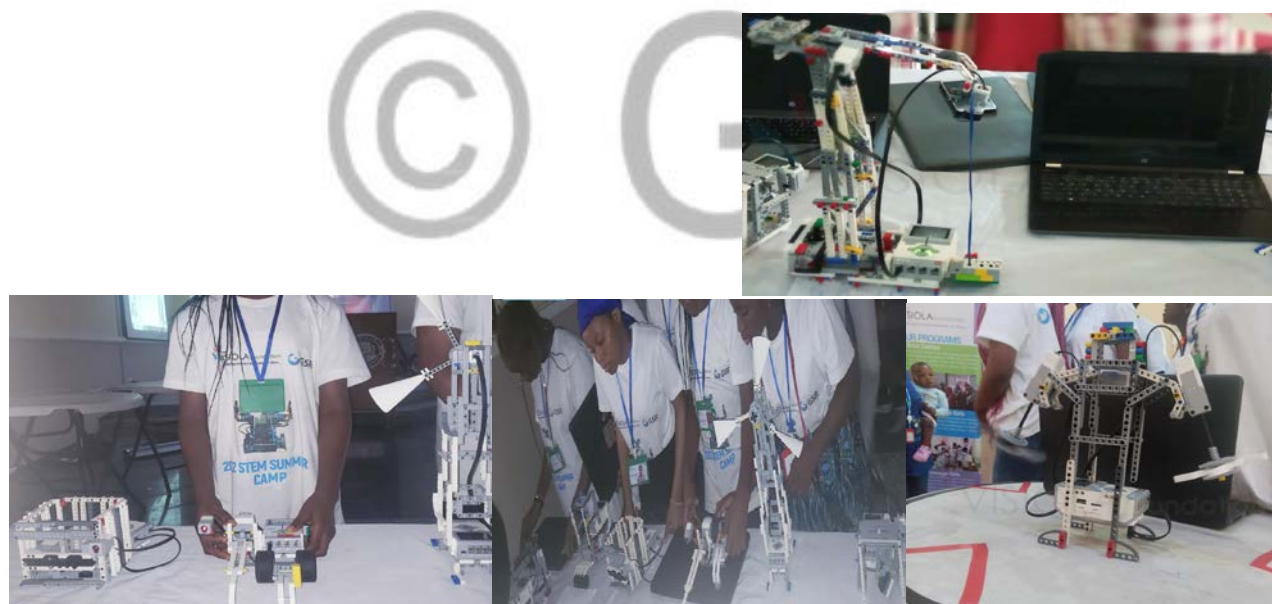


Fig. 3 Some of the final projects done by the students.

### 3) Breaking technology stereotypes

One intriguing feature of the robotics camp experience was how it challenged kids' preconceived notions about technology. When asked, "How did this experience impact how you think about technology?" 40.8% of students (N=50) said it was more difficult than they expected. One student, for example, stated that "this experience transformed how I think about technology since I assumed all technology was easy for me." After doing this job, I realized it was actually challenging." (9th grade girl, language arts accelerated). This was the question's highest-

scoring sub-code. We do not believe this merely means that pupils found the project too difficult. Instead, we feel that students developed a more realistic awareness of the difficulties that come with complicated, real-world engineering design issues. Examining all children in our selected group (7th and 8th grade on their first robotics experience) with post-survey findings, some (17.8%, N=50) stated that technology was more difficult than they had anticipated. 87.0% of these students said they enjoyed the project, while 13.0% said they didn't. To put it another way, just because students found technology more difficult than they expected does not mean they did not like the assignment. In contrast, 40.5% of students (N=50) indicated that technology was less difficult than they expected.

"After this experience, I believed that technology wasn't as complex as I imagined it would be and that it wasn't only a wonderful learning opportunity but also a fun endeavor," one student stated. 7th grade girl, advanced language arts. Because many students responded to the question, "How did this experience change how you think about technology?" With statements about how technology was either harder or easier than they had expected, it appears that first-hand experience assisted students in developing a more realistic metric of the complexity of technology development. This actual assessment of difficulty adds to the evidence that "the robotics summer camp promotes student foundation in technical knowledge and abilities."

TABLE III. DID YOU ENJOY DOING THIS PROJECT? WHY OR WHY NOT? RESPONSE SUMMARY

| <b>Did you enjoy doing this project?<br/>Why or why not?</b> | <b>Percent of Students<br/>N=50</b> |
|--|-------------------------------------|
| Yes - Technical Learning                                     | 40.5%                               |
| Yes - Enjoyed Technology                                     | 45.4%                               |
| Yes - Novelty of Experience                                  | 23%                                 |
| Yes - Teamwork (positive indication)                         | 65.4%                               |
| Yes – Fun Experience   | 56.4%                               |
| Yes - Enjoyed Building                                       | 25%                                 |
| Yes - Vague Learning Gain                                    | 45.5%                               |
| Yes - Creative   | 23.6%                               |
| No - Teamwork (negative indication)                          | 15.6%                               |

Students also stated that they had a greater appreciation for technology. 17.1% of students (N=50) said that it boosted their respect for technology in response to the question "How did this experience alter how you think about technology?" Increased appreciation responses might include admiration for the intricacy of technology, knowledge of technology's applicability in everyday life, or reporting a new viewpoint on technology. One

student, for example, stated, "This experience helps me appreciate folks who perform computer programming for a job." (7th grade girl, advanced language arts), and "This experience altered my perspective on technology since I used to believe that technology simply consisted of mobile phones and devices like that, but now I realize that there is more to technology than meets the eye." (10th grade female, accelerated language arts).

Students expressed a greater appreciation for technology in their replies to other questions as well, but in lower proportions: "Should other students have this experience?", 40.3% (N=50); and "What was the best thing you learnt throughout the project?" 50.2% (N=50). The stated rise in appreciation for technology reflects student views on the importance of technology in their lives and the globe. Because value is a motivating component, these data support the hypothesis about motivation and confidence.

Students reported learning about innovative uses of technology, which is not surprising considering the creative and multidisciplinary character of the robotics summer camp projects. In response to the question "What was the best thing you learned throughout the project?" 6.5% of students (N=50) highlighted the interdisciplinary nature of technology. "Energy transformation may be really tough to grasp," one student said, "but utilizing robotics and developing a visual perspective of it can help you understand it more." Female, eighth grade, advanced language arts. "Did you like working on this project?" 40.6% of students (N=50) said the assignment was enjoyable because it was innovative. For instance, a student stated, "Yes, I enjoy how individuals can be creative with their thoughts since there are so many possibilities to choose from." (8th grade female, accelerated language arts).

This acknowledgement of technology as a creative medium is consistent with both the definition of technology as the creative use of technology and the purpose of the robotics summer camp program, which is to provide a robotics intervention for girls that focuses on creativity and self-expression.

TABLE IV. HOW DID THIS EXPERIENCE CHANGE HOW YOU THINK ABOUT TECHNOLOGY? RESPONSE SUMMARY

| <b>How did this experience change how you think about technology?</b> | <b>Percent of Students<br/>N=129</b> |
|---|--------------------------------------|
| More challenging than I thought                                       | 17.8%                                |
| Gained appreciation for technology                                    | 17.1%                                |
| Technical Learning  | 13.2%                                |
| Less challenging than I thought                                       | 11.6%                                |
| No change reported  | 10.5%                                |
| Increased enjoyment of technology                                     | 15.6%                                |
| Increased perseverance  | 20.5%                                |
| Increased interest in technology                                      | 30.5%                                |

|                                      |       |
|--------------------------------------|-------|
| Increased confidence with technology | 40.5% |
| Found technology to be fun           | 45%   |

Finally, students claimed that the robotics summer camp influenced their thoughts on technical jobs or that the learning is relevant to their futures. When asked if "other pupils should have this experience?" Because it will benefit their future or job, 82.5% of students (N=50) replied yes. "I think other students should have this experience because it might boost your potential to one day go to college and maybe possibly have a profession in technology," one student remarked. (Female, 10th grade, advanced language arts). This was the second most popular response category for this question, behind only yes because it was entertaining (33.1%, N=50). This suggests that students respect the importance that technology may play in their classmates' future lives and jobs and believe that the robotics summer camp contributes positively to this role.

In summary, student responses indicate that students' understanding of the complexities of engineering design and technical projects became more grounded in reality, students came to appreciate technology in the larger world around them, students came to see that technology could have creative applications, and students considered the benefits of what they had learned from the project for their future lives.

## ***B. Complementary Non-Technical Skills***

### ***1) Teamwork***

We noticed indications of students gaining non-technical abilities in addition to the core aim of enhancing technology skills, knowledge, and attitudes that comprise student technological fluency. Teamwork and collaboration were two of the most prevalent non-technical abilities cited by students in their short answer replies. When asked, "What was the nicest thing you learnt throughout the project?" The second most popular code (22.3% of students) was only topped by learning about technology (56.8%). (N=50). One student, for example, stated that they learnt "not to criticize anyone for their errors because [you] will make at least one and you do not want to be blamed" (10th grade female, accelerated language arts).

TABLE V. SHOULD OTHER STUDENTS HAVE THIS EXPERIENCE? WHY OR WHY NOT? RESPONSE SUMMARY

| <b>Should other students have this experience? Why or why not?</b> | <b>Percent of Students<br/>N=50</b> |
|--|-------------------------------------|
| Yes – Fun Experience   | 33.1%                               |
| Yes – Novelty of Experience  | 18.5%                               |

|                                      |       |
|--------------------------------------|-------|
| Yes – Teamwork (positive indication) | 17.7% |
| Yes - Vague Learning Gain            | 15.4% |
| Yes - Technical Learning             | 10.0% |
| Yes – Career/Future Benefits         | 6.2%  |

Teamwork appeared in the responses to other questions as well. For “Did you enjoy doing this project?”, 13% of students (N=50) reported that they enjoyed the project because they enjoyed the teamwork. When asked “Should other students have this experience?” 10.0% of students (N=50) said yes because they would practice teamwork. For example, one student responded, "yes because it alters your perspective on how you can accomplish tasks and collaborate with other students." (10th grade girl, accelerated language arts) and "Yes, I believe a lot of people my age would appreciate this, because it brings together both tech aware individuals and those who can work effectively with their hands." Female, 10th grade, academic language arts This tendency is especially striking because neither the Attitudes nor Knowledge surveys expressly discuss collaboration. Following the summer robotics camp, we found a reduction in the proportion of students who agreed with the statement "It's vital to me to know more about technology than most others." A McNemar’s Test indicated this was a significant decrease in the proportion of students,  $\chi^2(1) = 6.7, n = 50, p = .014$ . At first glance, this decline in the perceived value of technological expertise appears depressing; nevertheless, we believe that the collaborative features of the summer camp project shift the relative value students assign to their knowledge and abilities. Some student responses to open-ended questions support this interpretation, such as "the best thing I learned in this project [project] was that everybody did something to help the group so it would be teamwork" (10th female, academic language arts) and "that you need to make sure everyone is working and following along to the best of their ability so you get it done quickly." (Female, 10th grade, advanced language arts).

Student remarks like the ones above strongly reinforce the premise that students not only learned the importance of communication and collaboration, but also grew to respect their colleagues' contributions to the successful completion of a technical project of this magnitude. Teamwork was such an important part of the student experience. We often hear from children who had bad collaboration experiences at summer camp. Negative collaboration was the most common negative response code for "Did you enjoy doing this project?" (4.6% of students, N=50). While the majority of students who mentioned cooperation thought it fun or productive, some reported unfavorable teamwork experiences. Anecdotal evidence from instructors suggests that cooperation is a particularly difficult topic for middle school pupils, therefore witnessing both good and negative reactions to teamwork is common.

The importance of cooperation in short response questions can be attributed to the important role that teamwork plays in summer camp projects. These summer camp projects were so large that no single student could accomplish them on their own. Furthermore, the intricate, interrelated structure of engineering design projects

necessitates tight collaboration among students rather than merely working in parallel. In summary, the robotics camp requires children to work together.

## **2) Other Skills**

While collaboration was the most often mentioned non-technical talent by students, numerous other abilities were mentioned in the open-ended question replies. The most prominent of these was perseverance, with 5.4% of students (N=50) indicating increased perseverance with technology in response to the question "How did this experience impact how you think about technology?" Responses saying that the project or technology was tough but rewarding or beneficial in the end, for example, "... The usage of the different robot parts was challenging but highly gratifying in the end, but not as challenging as predicted," were categorized into this category. Male, eighth grade, advanced language arts.

Perseverance emerged in lesser doses in answer to other questions, such as "What was the best thing you learnt during the project?" "Should other students have this experience?" 2.9% (N=50). 2.3% (N=50); 0.8% (N=50) for "Did you like working on this project?" A few pupils mentioned time management and problem solving abilities. In answer to the question, "What was the most important thing you learned during the project?" Time management was reported by 2.9% of students (N=50). When asked if other kids should have this experience, one student mentioned problem solving skills, stating, "Yes, it helps with collaboration and problem solving skills." (9th grade girl, language arts accelerated). Because the hypotheses, professional development, and assessment techniques did not explicitly target these abilities and dispositions, the findings imply an intriguing relationship for future work.

## **V. FUTURE DIRECTIONS**

In the future, we plan to continue to:

- 1) build on the above-mentioned outcomes, as not all outcomes could be provided within the scope of this research;
- 2) enhance the robotics camp system; and
- 3) investigate new areas of assessment. We intend to build on our results about the development of teamwork and other non-technical abilities by creating professional development and curricular resources to assist robotics camp teachers in maximizing these complementing advantages. We will also work to establish more detailed items for quantifying these non-technical achievements.

We are also interested in developing evaluations relating to the robotics camp's interdisciplinary character and curricular integration to assist analyze the influence of the robotics camp on student learning of the core discipline, such as poetry. While we have analyzed data from the whole population of robotics camp students, we

would gain more information by comparing subpopulations. To answer our program's aim and premise of "engaging a broad demographic of participants," for example, it will be necessary to analyze the knowledge and attitudes results from the experience by different genders and students with varied experience levels. It will also be interesting to do additional study of the variations in results between different student grade levels in order to assist instructors in selecting learning objectives that may be attained with this and comparable projects in their specific courses. Longitudinal examination of kids enrolled in various robotics camp courses offers another intriguing path for future research.

## **VI. CONCLUSIONS**

The outcomes of the middle school creative robotics project, as well as the robotics camp, were presented here. The purpose of the robotics camp program was to improve middle school pupils' technical proficiency. Students' self-reported learning and pleasure of the creative parts of technology as a result of their participation in the robotics camp provided evidence for this purpose.

Our hypothesis for evaluating the robotics camp program were as follows:

1. The robotics camp improves students' technical knowledge and skills.
2. The robotics camp boosts students' motivation and confidence in using technology.
3. The robotics camp attracts a diverse group of participants, both male and female, with varying levels of technology experience. Student self-reported technical learning, significant improvements in technology component identification, significant increases in understanding of systems engineering concepts, and short answer responses demonstrating the grounding of technology concepts through first-hand experience all supported the first hypothesis.

The second hypothesis was validated by self-reported confidence gains, a rise in students disagreeing with the statement "I am not excellent at constructing robots," and self-reported increases in student appreciation of real-world uses of technology.

The third hypothesis is currently being assessed and, as previously stated, will be the topic of future research. We also noticed high self-reported effects linked to cooperation outside of the initial predictions, which warrants additional specific study and augmentation through future program development.

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