AN ABSTRACT OF THE THESIS OF

Ernie Bodle for the degree of Master of Science in Electrical and Computer Engineering presented on November 20th, 2019.

Title: The Effectiveness of Using Robotics for Career Technology Education in a Middle School STE(A)M Course

Abstract approved:

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Jennifer Parham-Mocello

Using robotics in education allows students to become familiar with multiple topics in science, technology, engineering, and mathematics (STEM). With the use of robotic educational tools in the 8th – 12th grade classrooms, such as Sphero, Anki Cozmo, and Lego Mindstorms, few devices allow students to build the robots' electrical circuits along with constructing and programming. By incorporating electronics into these educational tools, students can learn another fundamental disciplines of robotics. For this research, we introduce the Parallax ActivityBot 360º to the Linus Pauling Middle School career technology education (CTE) course to see if the device promotes STEM. The ActivityBot 360º incorporates robotics, electronics, computer science, and mathematics into constructing and using the device. Students use the tutorials given online to assemble the robot and to program it with a block-based coding language called BlocklyProp with an option to use the text-based C language. The main idea is to find the effectiveness of this tool for CTE courses and how it can change students' interest, enjoyment, confidence, knowledge, and/or motivation to pursue a degree or career in STEM. For this research, we surveyed middle school students before and after using the device to see how their opinions and knowledge in STEM would change. From the results, we found that students' confidence in three of the four topics surveyed increased after using the ActivityBot 360º.

The Effectiveness of Using Robotics for Career Technology Education in a Middle School STE(A)M Course

by
Ernie Bodle

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Ernie Bodle, Author

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Chapter 1 Introduction

In the 8th-12th grade Career Technology Education (CTE) courses, technology can be used to expose students to different topics that could lead to interest in certain STEM careers. Products, such as the Arduino can be used to expose students to programming and building circuits with various electrical components. The Arduino, and similar devices, can be used to expose students to programing languages, such as C, Scratch, etc [10]. Block-Bases programming languages, like Scratch, can even be used as a gateway to introduce students to programming and robotics [10]. Programming and electronics are two of the several topics incorporated into robotics, which gives robotics versatility as a Science, Technology, Engineering, and Mathematics (STEM) learning tool.

The flexibility of robots allows for a variety of uses in education. Some robots can be used as learning assistants, such as Georgia Institute of Technology's intelligent assistant, Jill [12]. Other educational robots can be used for "medical training" or "intelligent toys for pre-school children" [12]. This paper focuses on the use of "multi-function suite robots", which are hands-on robots that aim to teach students about robotics by letting those students construct and program the devices [12]. Teaching students with these types of robots can expose them to a variety of different STEM topics, such as computer science, electronics, mathematics, etc. [8].

Preconstructed robots, such as Sphero and the Anki Cozmo, lets students program and apply the robot to solve a variety of problems. Being "one of the most popular" robot to be used in education, Lego Mindstorms allow students to program and construct the robot in a variety of forms [11]. With an abundant amount of literature surrounding the use of Lego Mindstorms, there lacks research on other similar robots in CTE courses. This paper will evaluate the effectiveness of the ActivityBot 360º in a middle school CTE course.

Chapter 2 Background and Motivation

2.1 Motivation for Research

In 2016, Measure 98 was passed in Oregon to fund CTE courses in high school and was amended in 2017 to include the 8th grade [4] [5]. CTE courses offer education for a variety of careers, such as health science, business, information technology, STEM, etc. The main goal of CTE is to help students develop skills that can be useful for future careers.

Linus Pauling Middle School, a Corvallis District dual-language (Spanish and English) immersion school, started the Science, Technology, Engineering, Art, and Mathematics (STE(A)M) CTE elective course in response to Measure 98. During the course's second year, a robotics intervention was introduced to the course. The ActivityBot 360º kits were used for this intervention and were provided by Parallax Inc.

The technology company Parallax Inc. wanted to research the effectiveness of the ActivityBot 360º kit in middle school CTE courses. Parallax wanted to evaluate how engaged students were towards STEM topics and how their engagements would change before and after using the device in the course. They also wanted to find out how students' attitudes towards majoring or working in a STEM related field would change after using the ActivityBot 360º.

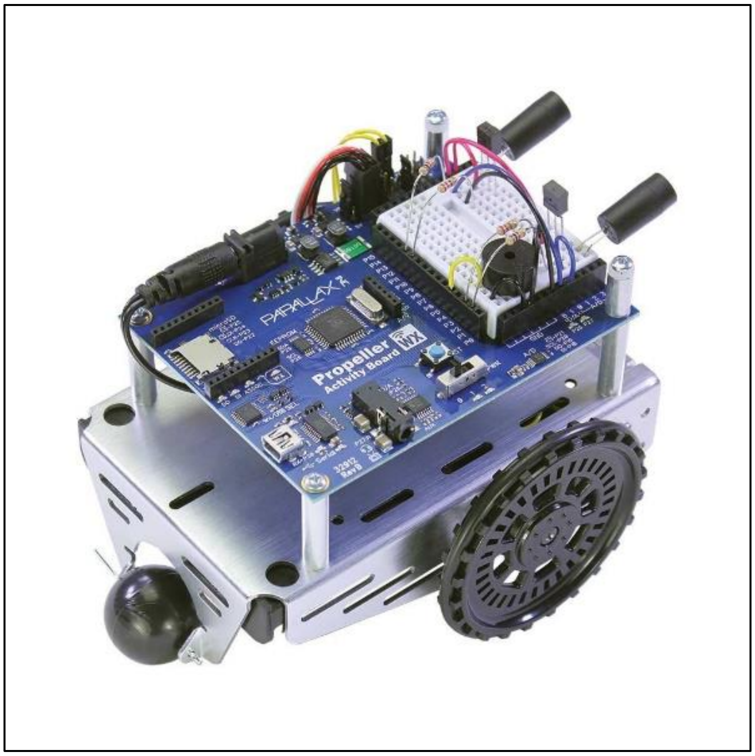

Figure 1. The ActivityBot 360º with Infrared Sensors and Emitter

2.2 The ActivityBot 360º

Shown in Figure 1, the ActivityBot 360º allows students to construct, wire up, and program the robot. The ActivityBot 360º kit consists of three wheels, a battery pack, two servo motors, multiple electrical components, a chassis, a Propeller Activity Board WX, and a few tools. The Propeller Board is a programmable printed circuit board (PCB) with a bread board and many ports attached. The ports and bread board allow student to customize and connect a variety of sensors and electrical components, such as the infrared emitter, infrared receiver, buzzer, and resistors to the robot. The parts just listed are shown connected to the device in Figure 1. For writing the programs that control the robot, students can either use the block-based programming language BlocklyProp or use the text-based C language. Block-based languages allow students to program without having to learn syntax that may be too complicated for students who are not yet educated in computer science. The students who have prior knowledge in text-based languages can use C instead of BlocklyProp. Both languages are used in the tutorials provided in the Learn Parallax website. The website also has tutorials on constructing the robot and how to connect each electrical component [1].

Chapter 3 Related Work

The research done by Chaudhary et al. and Knop et al. both evaluate the effectiveness of two different robots as a learning tool and tools to get K-8 students interested in STEM. Chaudhary et al. introduced the Lego Mindstorms EV3 to a summer camp for elementary school students. The camp had instructors teach a hands-on curriculum centered around the device for multiple days. Along with surveying the students about their experience, students were evaluated on their "computational and logical thinking skills" before and after taking the summer camp [11]. The evaluations were done by having students play an online game that focused on computational thinking using Scratch. The research concluded that students' engagement increased after taking the summer camp [11].

The research done by Knop et al. had middle school students learn how to build and use a "Neu-pulator platform", which is a robot that resembles a human arm. They had the students take a survey before and after the course to see how the students' interests in different topics would change. Knop et al. implemented daily surveys to measure how general confidence would change throughout the course. Through the surveys they found "an increase in the level of interest towards robotics among the students, with a significant increase for girls" [7].

The research done by Zygouris et al. introduces the Lego Mindstorms NXT to a group of 12-year-old primary school students. The device was used as a hands-on approach in teaching geometry to students. The researchers concluded that students who used the device gained more knowledge in geometry than a control group of students who had normal lecturing [9].

The research talked about above shows that implementing robotics in a classroom can influence student's attitudes and knowledge towards STEM and STEM related topics. This research hopes to find that similar results will occur when applying the ActivityBot 360º to a group of middle school STE(A)M elective students.

Chapter 4 Proposed Method & Experiment

4.1 Introduction to Methods

This research focuses on evaluating the effectiveness of the ActivityBot 360º for CTE courses and a way to change students' attitudes towards STEM. With such a broad research question to evaluate, the research question was split into different topics that are directly related to what the CTE course is trying to achieve. Effectiveness was evaluated by measuring the effect of exposure to the ActivityBot 360º and its tutorials had on student interest, enjoyment, confidence, knowledge, and/or motivation to pursue a degree or career in STEM. To answer these questions, middle school STE(A)M elective students were asked survey and quiz questions before and after the robotics intervention in the class.

In the fall of 2018, research was conducted in the Linus Pauling Middle School's STE(A)M elective course. This is the second year this elective was taught, and this was the first year it incorporated robotics into its curriculum. During the class, students worked in pairs with the robotics kit. These robotics kits hold parts to assemble the ActivityBot 360º and all its circuits. Students learned about robotics in class through the ActivityBot 360º tutorial and instruction from their teacher.

Parallax created a tutorial for the robot, which is located on the learn.parallax.com website. The tutorial consists of several parts, which explains how to construct, program, and set up the circuits to control the ActivityBot 360º. This tutorial shows and explains how to use each part that is provided by the robotics kit. The tutorial teaches students how to use BlocklyProp with an option to use the text-based language C. Similar to Scratch, BlocklyProp lets users link different configurable blocks together by dragging and dropping each block to create a program. The configurability allows users to create programs that are almost as complex as it's C counterpart (i.e. users can configure the loop block to control the number of iterations).

After obtaining IRB approval, a pre-survey, post-survey, and quiz were created in both English and Spanish to assess student engagement, attitude, knowledge, and general demographic data. While surveys and quizzes were reviewed by a licensed teacher and the director of the Oregon State STEM Academy, who runs STEM based summer camps for K-12 students, we recognize that the surveys and quizzes were not tested for reliability and validity using rigorous statistical methods. Before conducting the study, parents received a notification, in both English and Spanish, with an opt-out option for their child's participation in the study.

Before each survey, students were presented with an assent form to fill out through the online survey service, Qualtrics. Assenting students took the pre-survey and first iteration of the quiz on October 9th, 2018 while the post-survey and second iteration of the quiz January 30th, 2019. Surveys were designed to gather demographic data, student opinions, and student attitudes before and after using the ActivityBot 360º. After each survey, students completed a quiz to determine their initial knowledge and how their knowledge changed after the robotics intervention of the course. Students received surveys and quizzes online through Qualtrics.

4.2 Survey Questions

4.2.1 Demographic Questions

Questions were asked to gather information on students' interest and background, along with gathering traditional demographic data, such as gender, ethnicity, previous elementary school, and whether they receive free/reduced lunch to measure socio-economic status. According to the Oregon Department of Education's Student Group Definitions, students who are considered Economically Disadvantaged are defined as, "students eligible for free and reduced price lunch" [6].

Other questions, such as "Did you choose to take this STEM elective?" and "Have you attended any [STEM] related courses or camps[?]" were used to distinguish if students are actively pursuing STEM topics or not, and both questions included an open-ended follow-up question asking students to "state why [they] chose this STEM elective" and to "list the courses or camps you have already taken" respectively. In order to better understand students' exposure to STEM, student were asked to rank their interest on the topics shown in Table 4 with a binary scale of "Not interested at all" to "Extremely Interested," as they provided open-ended responses about what they liked or disliked related to robotics, electronics, programming / computer science, and mathematics. Lastly, students were then asked to list if they had any friends or family working in STEM fields.

4.2.2 Pre and Post-Survey Questions

Several questions were used to evaluate student attitudes and how those attitudes towards STEM topics changed after the robotics intervention of the course. These questions were included in the pre-survey and post-survey. In one set of questions, students were asked to rank their enjoyment, confidence, and motivation to pursue a career or degree on a five-point Likert scale for four different STEM topics. The topics listed were robotics, electronics, programming / computer science, and mathematics. One question asked students to rank their interest on a five-point Likert scale for the STE(A)M elective course specifically. The last pre/post-question asked students if they do or do not consider pursuing a career or degree in STEM. If they consider pursuing a STEM career or degree, an open-ended question was asked to see which STEM field students were most interested in pursuing. If they chose no, they were then asked why they did not want to pursue a career/degree in STEM.

4.2.3 Follow Up Questions

To obtain insight on what students liked/disliked and what problems may have caused them to change their opinions, several follow-up questions were added to the post-survey. The first set of questions asked students to rank their enjoyment on a five-point Likert scale for various topics that revolved around the ActivityBot 360º. The topics were programming with BlocklyProp, constructing the robot, wiring up the robot, robot navigation, and playing with sensors. They were then asked to rank their motivation to solve problems, when problems arose, for those same topics on a five-point Likert scale. The last question asked students if they were able to solve most of the problems they faced with the robot.

4.3 Quiz Questions

4.3.1 Introduction to the Quiz

An identical pre and post quiz was given to see if student's knowledge in STEM topics changed after the robotics intervention. Students take the same quiz after completing both the pre-survey and post-survey. The quiz is 8 questions which is split up into three different categories. The first category of question gauges how familiar students are with different electrical and robotic components or their corresponding schematic symbols. The second category involves using mathematics to solve a problem that will be encountered during the ActivityBot 360º tutorial. The last category tests computational thinking with the use of flowcharts.

4.3.2 Part Identification

Question 1 of the quiz asks the student to correctly match an image of an LED, resistor, and servo motor to their corresponding name. Question 2 has students identify an electrical schematic symbol of a resistor, given four possible answers for that symbol. Instead of matching the symbol to a name, Question 3 has students determine if an LED in an electrical circuit schematic is placed in the correct orientation. Question 6 of the quiz shows an image of a robot with four arrows pointing to different parts of the robot. It then asks students to identify the correct arrow that points to the chassis of the robot.

All the parts and symbols in the quiz are encountered while constructing the ActivityBot 360º and its circuits. Resistors are introduced in the Build the Whisker Switches step in the Navigate by Touch section of the ActivityBot 360º tutorials. The Blink Lights step of the ActivityBot 360º Circuits section introduces the LED schematic symbol, while an actual image of a LED is shown during the Build the IR Sensor Circuits step in the Navigate by Infrared Flashlights section. The chassis and the servo motor are shown in Step 2 and Step 3 of the Build the ActivityBot 360º section respectively [1].

4.3.3 Applied Mathematics

The step, Driving Distances, in the Navigation Basics section of the tutorial explains how students can use BlocklyProp and basic math skills to move the ActivityBot 360º specific distances [1]. Reflecting this step, Question 2 asks how far a robot would travel, given how many millimeters per tick, how many ticks per rotation, and how many times the wheel rotates. This question focuses on how students can apply mathematics to solve problems in robotics.

4.3.4 Computational Thinking

The last category of quiz questions tests students' computational thinking. Since students are being tested on computational thinking and logic instead of syntax of a programming language, flowcharts were used for these problems. Students learn graphic organizers, such as flowcharts, through the Engage New York curriculum, which is used before middle school in the Corvallis School district [2] [3]. Question 5 shows a simple maze and asks students to choose the simplest set of instructions for a "mouse" to follow to get to a piece of "cheese." Each possible answer is written in a flowchart format. Question 7 and 8 has students follow a logical flowchart, similar to simple programs, to see if students can follow this logic.

Chapter 5 Results and Discussion

5.1 Demographics

Table 1. Traditional Demographics

Gender	# of Students
Female	15
Male	42
Ethnicity	**# of Students**
Hispanic	11
Non Hispanic	46
On Free/Reduced Lunch	**# of Students**
No	38
Prefer not to answer	5
Yes	14
Elementary School	**# Students**
Adams	13
Garfield	10
Hoover	4
Jefferson	12
Lincoln	4
Muddy Creek Charter	2
Multiple	2
Other	10

With respect to the 57 students at Linus Pauling Middle School who participated in both the pre-survey and post-survey, only 15 were female while 42 were male. Shown in Table 1, 11 out of the 57 students were Hispanic and 14 out of the 57 students claimed to be on free/reduced lunch. 49 out of the 57 students came from Corvallis School District elementary schools. Shown in Table [school], students who were placed into the “Multiple” category went to more than one elementary school. Elementary schools that were only listed once, such as “Central Albany Elementary school”, were grouped together into the “Other” category.

Table 2. Results for “Did you choose to take this STEM elective?” and its Follow-Up Questions

Choose to take this STEM elective?	# of Students
No	20
Yes	37
If No - Reasons for Being in this Elective	**# of Students**
No Choice	17
Not Sure	1
Other	2
If Yes - Reasons for Choosing this Elective	**# of Students**
Interest / Enjoy STEM Topics	24
No Choice	2
Not Sure	2
Other	2

For the 20 Linus Pauling Middle School students that did not choose to take this elective, 17 stated that they had no choice in the matter, 1 student stated that they were not sure, and 2 students had incomplete answers. Students who were placed into the “No Choice” category typically responded with answers like, “I was put in it by the school.” or “I did not choose to be here.” The student who was placed in the Not Sure category stated, “I don’t really know.” The two students who were categorized into the Other category answers stated, “Because I like to build stuff” and “Fun.” Three students who stated that they did not choose to take this elective also stated that they were excited or interested in taking a STEM course. Those students answered with, “I’m not sure. I didn’t sign up for STEM but I’m actually really excited to t[a]ke this class”, “I didn’t really choose to be here, but it’s fun and I guess it’s something new”, and “I didn’t sign up for stem but I wanted to do STEM.”

For the 37 students who stated that they did choose to take this elective, 24 of them stated that they chose this elective due to interest or enjoyment in STEM topic, 2 of them stated that had no choice in the decision of taking this elective, 2 stated that were not sure why they were in the elective, 2 had other reasons, and 7 decided to take this elective because they wanted to learn about STEM topics. Shown in Table 2, students who were placed into the Interested/Enjoy STEM Topics category had responses like, “Because I enjoy math, technology, science, and engineering”, “I chose stem because it was the most interesting elective that I could do”, or “I chose it because it sounded fun and interesting.” Due to the similarity of responses, interest and enjoyment were placed into the same category. Students that expressed that they wanted to learn about STEM topics were placed into To Learn STEM Topics. The 2 students who were placed into the "Other" category stated, "Thought it was something else" and "Oregon." There were 2 students who stated that they did not chose to take this elective in the free response, even though they stated that they chose to take this elective.

A Kruskal-Wallis Test was used to see if different traditional demographical groups differed in their results. After running tests, it was found that the groups in gender, ethnicity, and economical status differed from each other in their responses for the question, "Did you choose to take this STEM elective?".

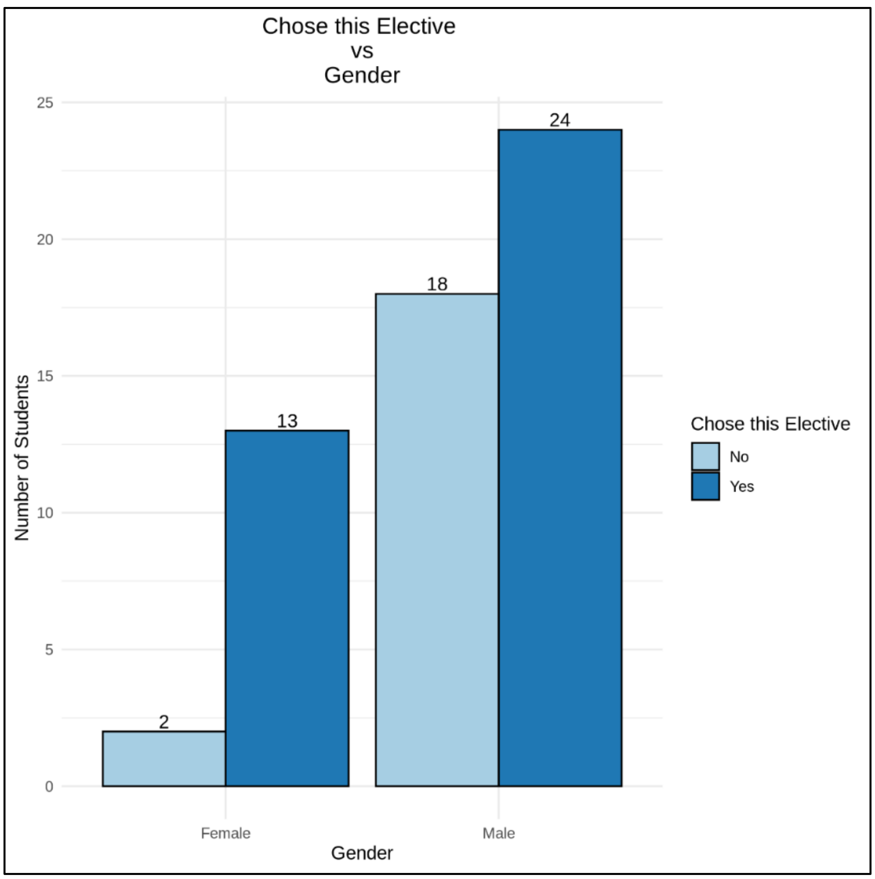

Figure 2. Responses for "Did you choose to take this STEM elective?" for each Gender

In Figure 2, 13 out of the 15 female students chose to take this elective, while 24 out of the 42 male students did the same. This different ratio in the responses for each group caused a p-value of 0.0415 to be returned. Since that value is less than the 0.05 significance level, it can be confirmed that there is a significant difference in responses for each gender group.

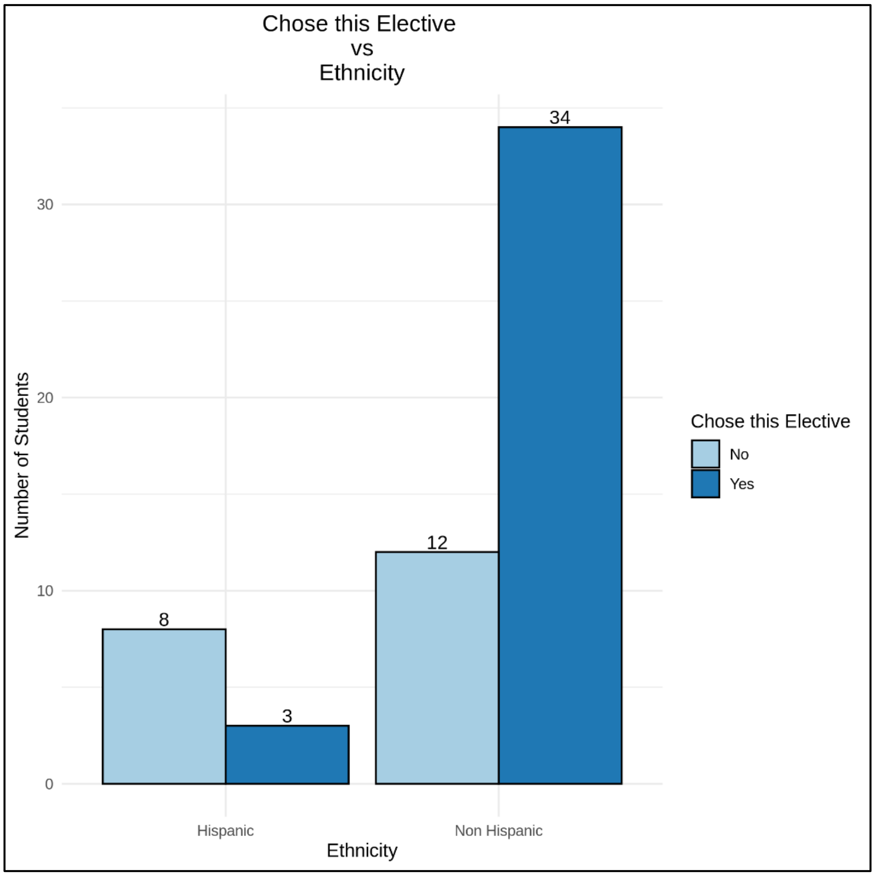

Figure 3. Responses for “Did you choose to take this STEM elective?” for each Ethnicity

In Figure 3, 3 out of the 12 Hispanic students chose to take this elective, while 34 out of the 46 non-Hispanic students did the same. This different ratio in the responses caused a p-value of 0.0039 to be returned. Since that value is less than the 0.05 significance level, it can be confirmed that there is a significant difference in responses for each ethnic group.

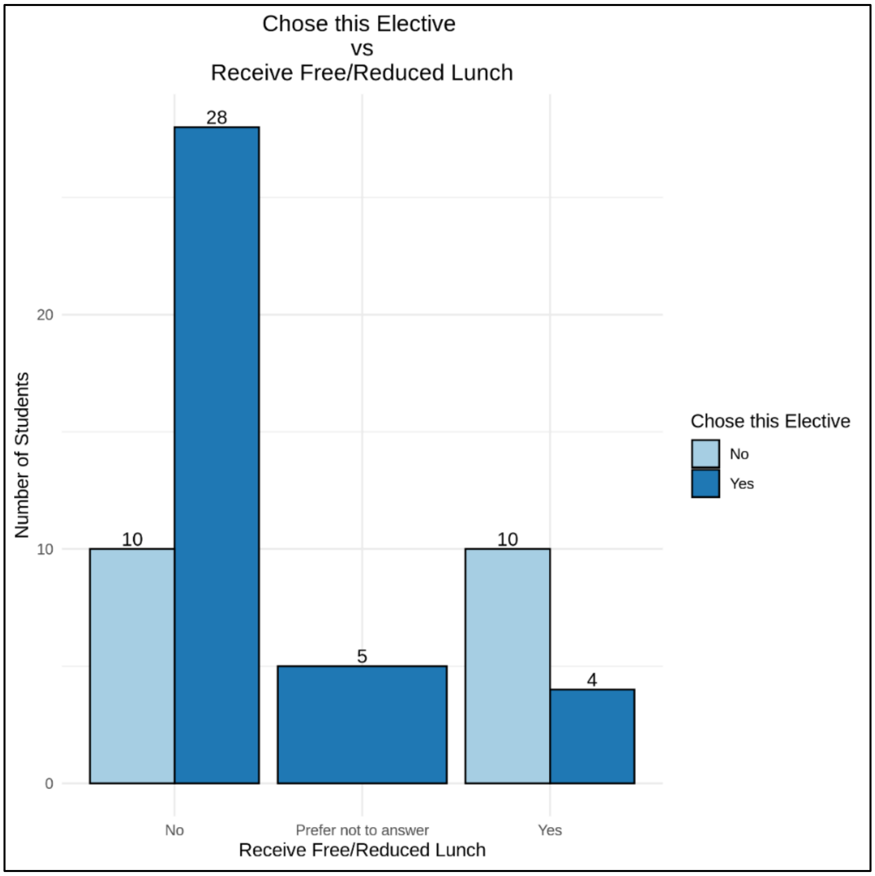

Figure 4. Responses for “Did you choose to take this STEM elective?” for Each Economical Group

In Figure 4, 28 out of the 38 students who answered “No” to the “Do you receive free and reduced lunch?” stated that they chose this elective, while 4 out of the 14 of the students who answered “Yes” did the same. All 5 students who chose not to answer stated that they chose this elective. This data shows that students who do not receive free/reduced lunch are more likely to choose if they are in this elective. This different ratio in the responses for each group caused a p-value of 0.0026 to be returned. Since that value is less than the 0.05 significance level, it can be confirmed that there is a significant difference in responses for each economical group.

Table 3. Table of the Courses/Camps Listed by Students

Attended Other STEM Courses/Camp?	# of Students
No	33
Yes	24
STEM Course Attended	**# of Students**
3D Printing	1
Adventures in Learning	1
Digital Art	1
LEGO Robotics	6
Math	1
None	2
Not Sure	2
OMSI Camp Handcock	1
OSU Programming	2
OSU STEM Summer Camp	1
Programming	2
Research with Family	1
Robotics	3
Science	1
STEM Course	1
Summer Expeditions Cryptology	1
TAG Course	2
Women That STEM	1

Table 3 displays a list of STEM based camps/courses that students stated they attended. Students can state more than one camp/course attended. For the 6 of the 24 students who stated that they did attend a previous STEM course/camp also stated that they attended a Lego Robotics course/camp. 2 students stated that they did not attend any course/camp in the free response, even though they stated "Yes" on the previous non-open-ended question. In Table 3, OMSI stands for Oregon Museum of Science and Industry, OSU stands for Oregon State University, and according to the Oregon Department of Education, TAG stands for students who are Talented and Gifted [6]. Since some student specified that they attended a Lego Robotics course/camp, "Robotics" and "Lego Robotics" were split up into different categories. The student who was put into the "Research with Family" category stated, "I helped my Dad with his research on Green Hermit hummingbirds and their relationship with heliconia tortuosa by going out into the field a little to write down the data and watch."

Table 4. Frequency Students Interested or Not Interested in Certain Topics

Rate Your Interest In The Following STEM Topics	Not Interested At All	Extremely Interested
3D Printer	2	55
Programming Robots	8	49
Making Your Own Webpage	26	31
Making Your Own Apps	15	42
Making Your Own Video Games	10	47
Designing 3D Shapes on Computers	10	47
Writing Your Own Computer Programs	21	36
Making Your Own Animations	14	43
Designing Your Dream Home	13	44
Making Things Move with Motors	11	46
Creating Art on Computers	27	30

Table 5. Other Elective Topics that Interested Students

List any STEM Electives Not Mentioned Above That Interest You	# of Students
Electronics	1
Gardening	1
K'NEX	1
Life Science	1
Research Skills	1
Movies	1
Building	1
Engineering	1
Robotics	3

Student were asked to rate their interest in different topics. Shown in Table 4, students were the most interested in "3D Printers", while the second top picked was "Programming Robots". Students were least interested in "Creating Art on Computers" and "Writing Your Own Computer Programs". As a follow up to these questions, with the results shown in Table 5, students were asked to list any other STEM elective topics that interested them. The most listed STEM elective topic was "Robotics" with 3 mentions. It is being assuming that "knechs" is referring to the K'NEX building toy in the response, "I think the knechs where interesting."

Table 6. Students Free-Response Opinions on Robotics

Like - Robotics	# of Students	Dislike - Robotics	# of Students
Aesthetics	1	Boring	2
Application	9	Challenge	2
Building	10	Complexity	1
Challenges	3	Inadequate Workplace	1
Creativeness	2	Incomplete Answer	4
Engineering	1	Not Interesting	1
Enjoyment	1	Technical Problems	1
General	1	Time Commitment	3
Incomplete Answer	4		
Programming	1		
Satisfaction of Creation	2		

Table 7. Students Free-Response Opinions on Electronics

Like – Electronics	# of Students	Dislike – Electronics	# of Students
Application	7	Boring	1
Building	1	Building	1
Challenge	2	Comprehension	1
Circuits	1	Difficulty	1
Complexity	2	Inadequate Workplace	1
Designing	1	Incomplete Answer	3
Discovery	2	Robotics	1
Electronics	1	Slow Speed	2
Engineering	1	Small Things	1
Enjoyment	2	Technical Problems	2
Entertainment	1		
General	4		
How Advanced Electronics Are	1		
Incomplete Answer	3		
Interest	1		
Mathematics	1		
Repairing	1		
Soldering	3		
Usability	1		

Table 8. Students Free-Response Opinions on Programming / Computer Science

Like – Programming / Computer Science	# of Students	Dislike – Programming / Computer Science	# of Students
Application	1	Boring	1
Challenge	2	Deconstruction	1
Complexity	3	Difficulty	2
Creation	2	General	1
Enjoyment	3	Incomplete Answer	2
General	3	Lack of Physical Application	1
Hands On Work	1	Learning	1
Incomplete Answer	2	Tediousness	2
Interest	1		
Learning to Code	1		
Mathematics	1		
Programming	3		
Programming Video Games	1		
Robotics	2		
Satisfaction of Creation	3		
Video Game Programming	1		
Video Games	1		

Table 9. Students Free-Response Opinions on Mathematics

Like – Mathematics	# of Students	Dislike – Mathematics	# of Students
Application	3	Addition	1
Challenge	5	Boring	1
Complexity	3	Difficulty	7
Convergent Problems	2	Explaining	1
Enjoyment	3	General	2
General	7	Incomplete Answer	3
Geometry	1	Lack of Creativity	1
Incomplete Answer	3	Reviewing	1
Learning	2		
Mental Math	1		
Repetition	1		
Satisfaction in Completion	2		

Four open-ended questions were asked to gain further insight on what students like or dislike about robotics, electronics, computer science, and mathematics. Students can have multiple answers which can show both negative and positive opinions. In tables 6, 7, 8, 9, students who were categorized in “General” responded with a general like or dislike for those topics without further reasoning. Examples for “General” are, “I just like robots” and “I like everything.” Students who responded with an ambiguous answer were placed in “Incomplete

Answer". "You can program them" is one example of an incomplete answer for the question, "What do you like or dislike about Electronics?" due to it not clearly stating an opinion. The "Application" category was for student responses that stated that they like how these topics can be applied to perform different tasks or solve problems. Examples of "Application" are, "I enjoy building things that preforms tasks" and "I like that we use electricity to do stuff."

In Table 6, one student was placed into the category of "Aesthetic" because they stated that, "I think they look and sound cool. It would be fun to make your own little friend". In table 7, one student was placed into the "Mathematics" category due to their response, "I like electronic because it has to do a lot with math." The student who was placed into the "Small Things" category in Table 7 just stated, "I dislike all the small things."

Table 10. Table of Experience with Robotics

Experience – Building / Programming Robots	# of Students
No	23
Yes	34
Please select what you have experience with	**# of Students**
ActivityBot	1
Cozmo	1
Home Made Robots	1
Sphero	1
Robot Arm	2
UROV	2
Other	5
Random Class Robots	12
Lego Robotics	21

Table 11. Table of Experiences with Electronics

Experience – Building / Designing Electronics	# of Students
No	33
Yes	24
Please select what you have experience with	**# of Students**
Arduino	2
Audio Circuits	3
Basic Bread Boarding	8
Building circuits that move motors	13
Building RC Car	4
Computer	1
Electronics Kits	13
Radio	1
Under Water Rover (UROV)	4

Table 12. Table of Experiences with Programming / Computer Science

Experience – Programming / Computer Science	# of Students
No	20
Yes	37
Programming Languages Used	**# of Students**
Android	1
Blocklyprop	1
Ruby	1
HTML	1
Sphero	1
Arduino	1
Python	2
C/C++	2
Java	6
Mindstorms	11
Block	12
Scratch	21
Swift	27

Table 13. Listed Programming Projects Done by Students

List Any Programming Projects	# of Students
Animation	1
Code.org	1
Commands	1
Lego Robots	2
Miscellaneous	5
Scratch	1
Sphero	1
Swift Playgrounds	1
Video Games	6
Website	1

Students were asked if they had experience with robotics, electronics, and computer science. After each question, students were then asked for their specific experience for each topic. More than half of the students stated that they had experience in robotics and programming / computer S\science, while only 24 out of 57 students had experience with electronics.

In Table 10 and 11, the category "UROV" stands for Underwater Remotely Operated Vehicle (UROV). In Table 10, responses that were placed into the "Other" category did not fit into a specific category. Examples for the "Other" category are "Building a Star Wars drone" and "Pencil sharpener." For the students who had experience with robotics, 21 out of 34 of them had experience with "Lego Robotics", which is the largest group of experiences.

For experience with electronics, one student stated that they had experience with, "Computers a bit and electric cars and all that." This response was placed into "Building circuits that move motors" and "Computer" category, which is shown in Table 11. It is unclear if they were referring to using computers or working with computer hardware. For the students who had experience with electronics, shown in Table 11, "Electric Kits" and "Building circuits that move motors" were the largest categories.

Out of the students who had experience with programming / computer science, more than half had used the programming languages Scratch and Swift, which is shown in Table 12. About 30% of the students who had experience with programming stated that they have used block languages and Lego Mindstorms programming. In Table 13, 5 students were placed into the "Miscellaneous" category. This category was for responses that either never specified what they programmed or did smaller coding project (Such as practicing python on websites).

Table 14. Table of Results for the Question "Do you have any friends or family who"

Friends / Family	No	Not Sure	Yes
Know how to Program	10	26	21
Build / Program Robots	18	29	10
Build / Design Electronics	29	25	13
Work in STEM	16	16	25

Table. 15. Table of Listed Careers of Student's Friends / Family

Friends / Family - Work in STEM	# of Students
Chemical Engineering	1
Civil Engineering	3
Computer Science	4
Electrical Engineering	6
Environmental Engineering	3
Mathematics	2
Mechanical Engineering	3
Medical	1
Other	1
Robotics	1
Science / Research	6

Student were asked if they had any friends or family who know how to "Program", "Build / Program Robots", "Build / Design Electronics", and "Work in STEM" to gain insight on if they were exposed to these topics from their family or friends. Shown in Table 15, students who stated that they had friends or family who worked in "Coding" or "Software engineering" were categorized into "Computer Science". For answers that were categorized as "Science / Research", students wrote down "Archaeology", "Volcanology", "Forest Ecology", "Horticulture", etc. One student stated, "My uncle tests components that go on satellites and things at NASA." Since "components" could refer to a wide arrange of things, that response was placed into "Other". 25 out of the 57 students surveyed stated they had friends or family who worked in STEM, which is about 43.85% of the class.

5.2 Pre and Post-Survey Results

For the students who participated in both surveys, a Wilcox Signed-Rank Test was used to determine if there was a change in interest, enjoyment, confidence, motivation to pursue a degree/career, and knowledge, from pre-survey to post-survey. This paired test takes in 2 data sets of an identical population and returns a specific p-value. P-values that are less than the 0.05 significance level represents a significant change from pre-survey to post-survey.

A Kruskal-Wallis Test was used to determine if demographical groups differed significantly in answering each question. This test takes in survey and demographic data for a population and returns a specific p-value. P-values that are less than the 0.05 significance level represents that the demographical groups being compared had significantly different results. It should be noted that demographical groups with an n lower than 10 should have its significance excluded.

5.2.1 Student Interest

RQ1: *Does exposure to the ActivityBot 360 change students' interest in this STE(A)M elective?*

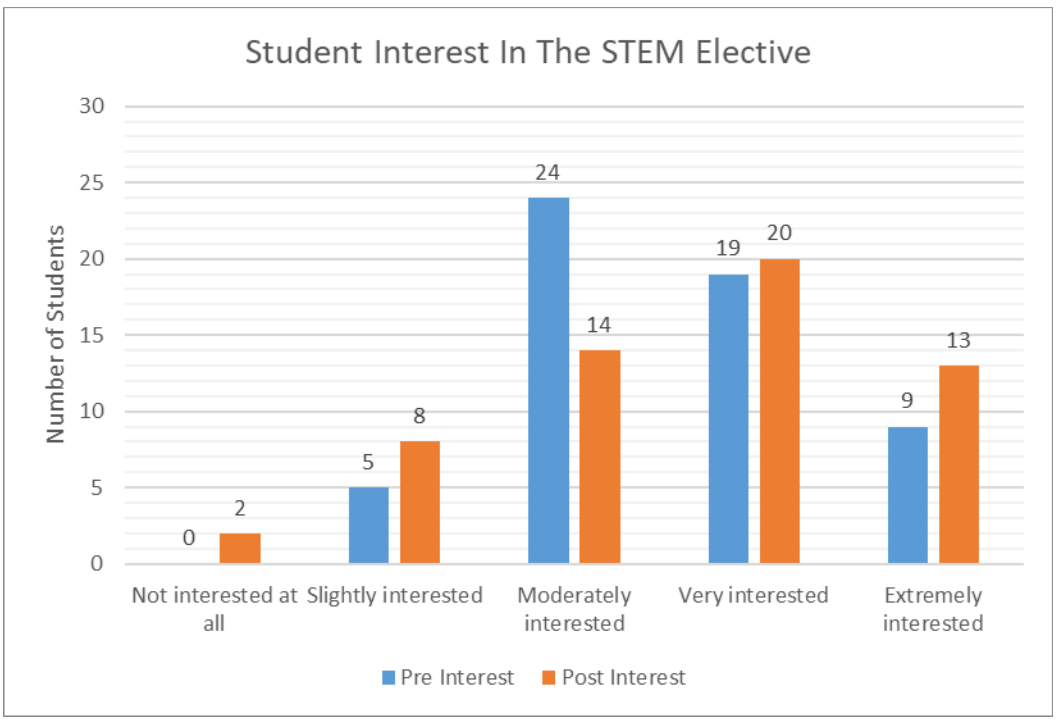

Figure 5. Frequency of Interest levels for the Pre-Survey and Post-Survey

NULL Hypothesis: There is no significant differences for the pre and post-interest in this elective for the two identical populations.

For testing this hypothesis, the two datasets were passed into a Wilcox Test. The resulting p-value for this test was 0.7544, which is greater than the 0.05 significance level, therefore we accept the NULL hypothesis. There are differences in the results, however they are not significant enough to state that there was a significant change in interest from pre-survey to post-survey.

When testing to see if traditional demographical groups differed, “Gender” and “Ethnicity” returned a p-value greater than 0.05, therefore those groups do not differ significantly. For the different economical groups, p-values of 0.0092 and 0.0497 are returned for the pre-interest and post-interest respectively. Therefore, there are significant differences between economical groups for both pre-interest and post-interest.

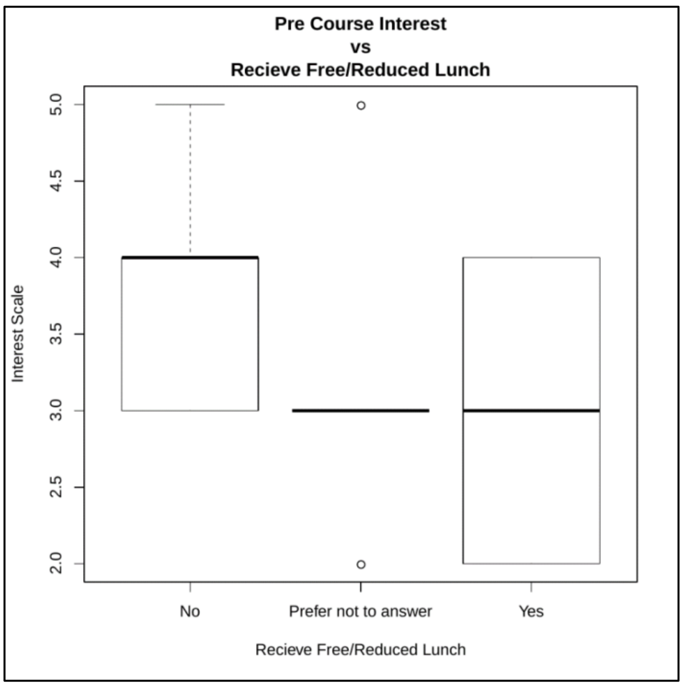

Figure 6. The Receive Free/Reduced Lunch Group Difference for Pre-Interest

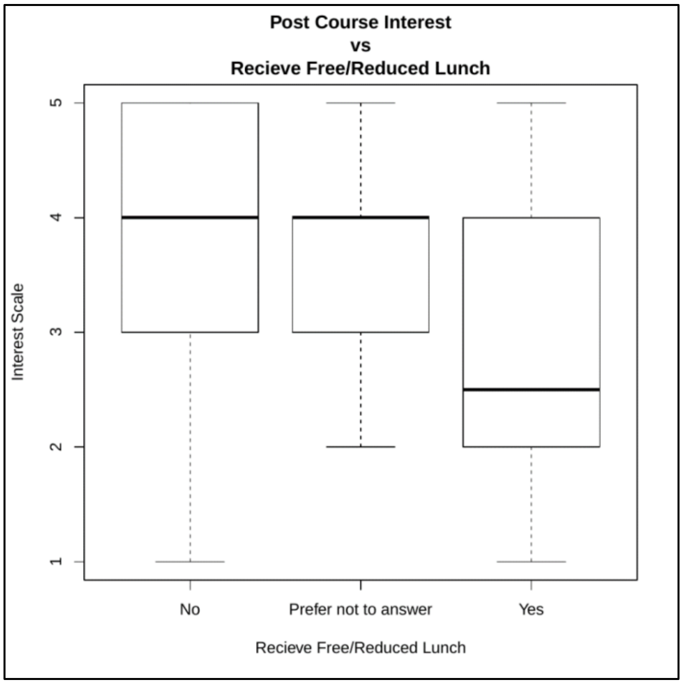

Figure 7. The Receive Free/Reduced Lunch Group Difference for Post-Interest

Shown in Figure 6 and 7, students who do not receive free/reduced lunch have a generally higher interest level than the other two groups. In these figures, the interest scale of 1 to 5 corresponds to “Not Interested at All” to “Extremely Interested” respectively.

5.2.2 Student Enjoyment

RQ2: *Does exposure to the ActivityBot 360^{o} change students' enjoyment in STEM fields?*

Table 16. The Returned Wilcox P-Value for Pre/Post-Enjoyment

Enjoyment	Pre Post Pvalue
Robotics	0.7681
Electronics	0.9188
Computer Science	0.8426
Mathematics	0.0971

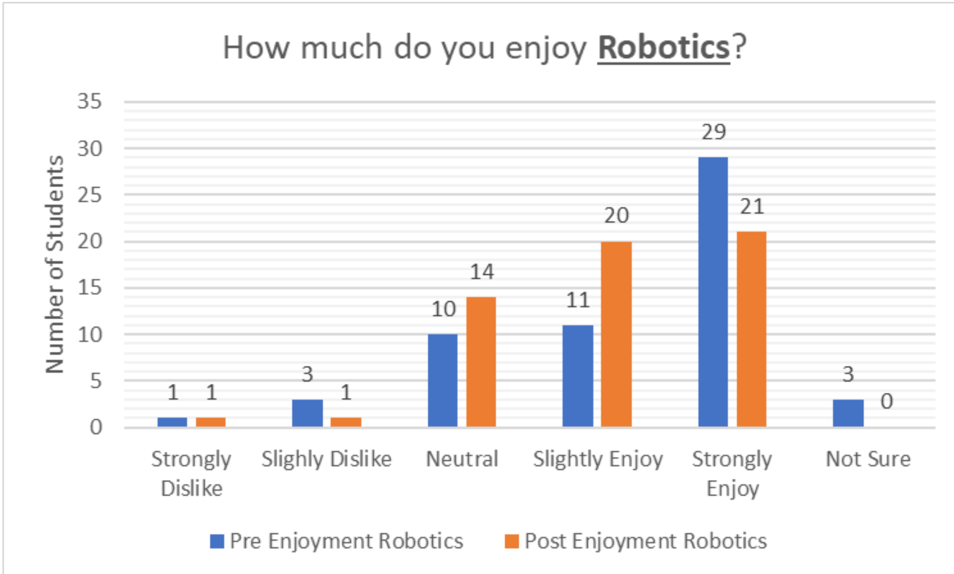

Figure 8. Frequency of Enjoyment Levels for Robotics

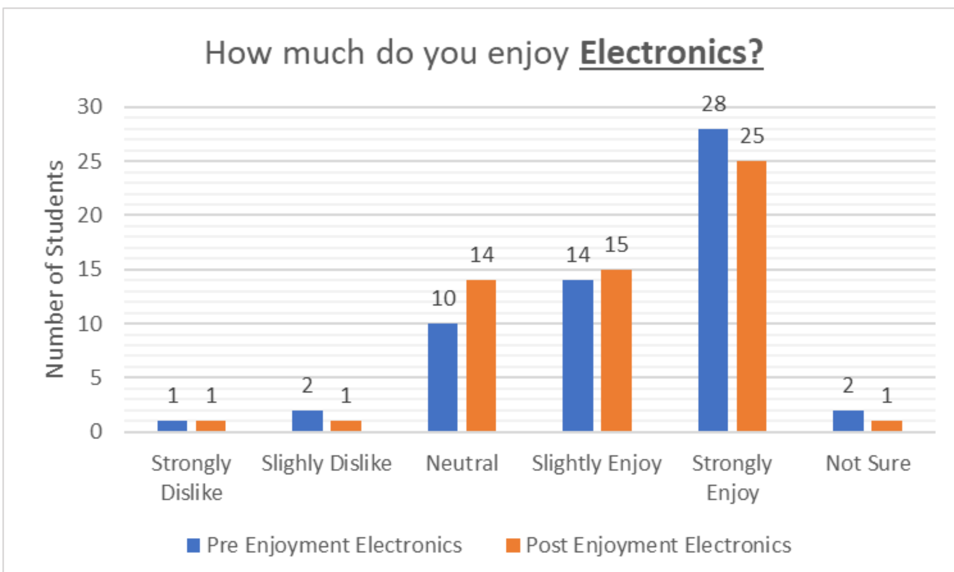

Figure 9. Frequency of Enjoyment Levels for Electronics

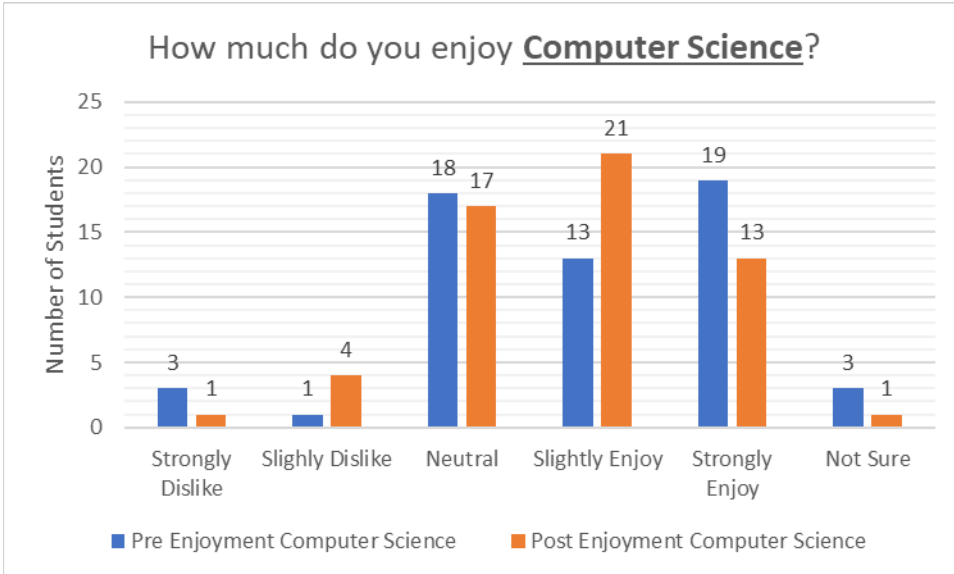

Figure 10. Frequency of Enjoyment Levels for Computer Science

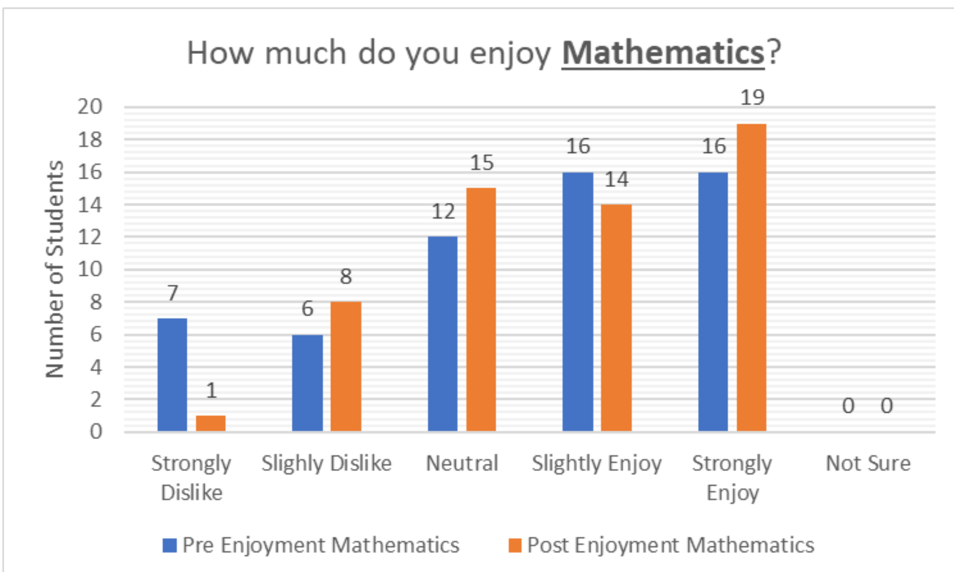

Figure 11. Frequency of Enjoyment Levels for Mathematics

NULL Hypothesis: There are no significant differences for the pre and post-enjoyment in the topics of Robotics, Electronics, Computer Science, and/or Mathematics for the two identical populations.

For testing this hypothesis, the pre and post-enjoyment datasets were passed into a Wilcox Test for all four of the topics. The resulting p-values, which are shown in Table 16, for this test are 0.7681, 0.9188, 0.8426, and 0.0971 for “Robotics”, “Electronics”, “Computer

Science", and "Mathematics" respectively. The p-values for each topic are all greater than the 0.05 significance level, therefore we accept the NULL hypothesis. Even though there are differences in the results, those difference are not significant enough to state that there is a significant change in enjoyment from pre-survey to post-survey.

When investigating if traditional demographic groups differed in their results, gender returned a p-value greater than 0.05 for all topics which signifies that there are no differences between the listed genders' enjoyment. When tested with different ethnic groups, p-values of 0.0320 and 0.0253 were retuned for pre-enjoyment in mathematics and post-enjoyment in mathematics respectively, while a p-value greater than the 0.05 significance level was returned for the difference of those enjoyment. Therefore, there are significant differences in enjoyment in mathematics for the different ethnic groups for both pre-survey and post-survey, but there are no differences in how this enjoyment changes. All other topics returned a p-value greater than 0.05 when comparing ethnic groups. When tested with the different economical groups, a p-value of 0.0469 was returned for pre-enjoyment in mathematics, while p-values greater than the 0.05 significance level were returned for post-enjoyment in mathematics and the difference of those enjoyments. Therefore, there are significant differences between the 3 economical groups and their pre-enjoyment in mathematics, but not with their post-enjoyment in mathematics and how those enjoyments differed from pre-survey to post-survey. All other topics returned a p-value greater than 0.05 when comparing economical groups.

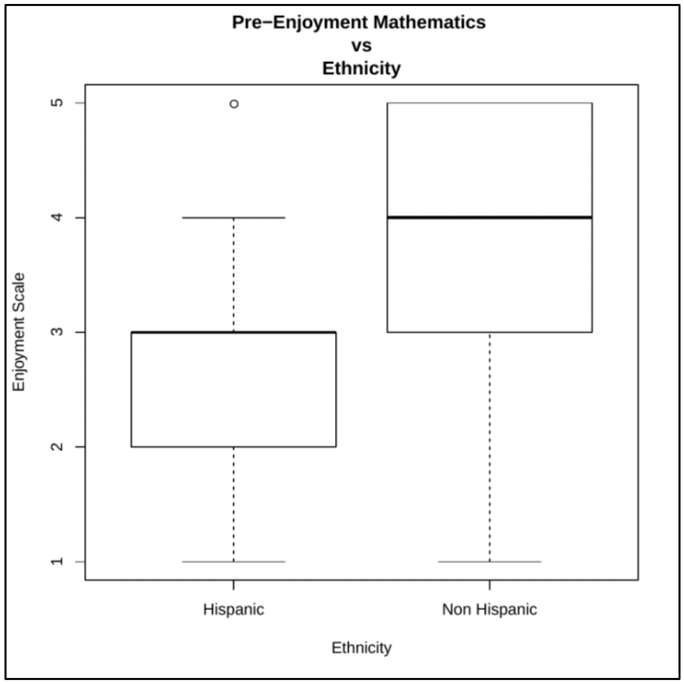

Figure 12. The Ethnic Group Differences for Pre-Enjoyment in Mathematics

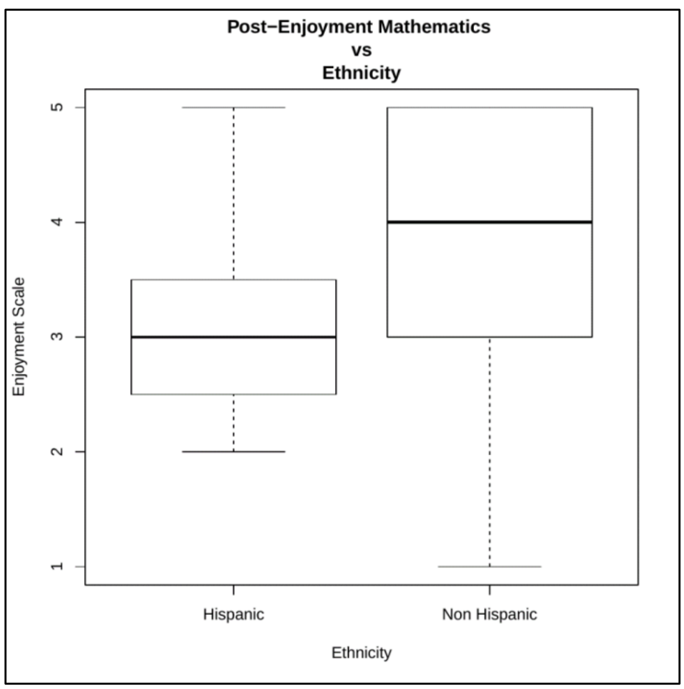

Figure 13. The Ethnic Group Differences for Post-Enjoyment in Mathematics

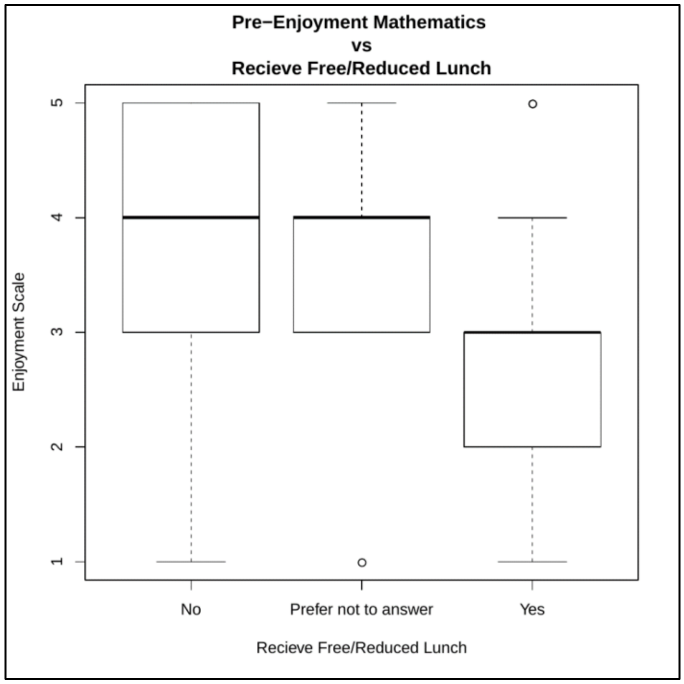

Figure 14. The Economical Group Differences for Pre-Enjoyment in Mathematics

For Figure 14, 12, and 13, the enjoyment scale of 1 to 5 refers to “Strongly Dislike” to “Strongly Enjoy” respectively. Shown in Figures 12 and 13, the “Hispanic” group of students had a lower overall enjoyment in mathematics. Hispanics also showed a small increase of enjoyment in mathematics from pre-survey to post-survey. The “Non Hispanic” group of student stayed relatively constant from pre-enjoyment to post-enjoyment.

Shown in Figure 14, the group of students who did not receive free/reduced lunch had the widest range of enjoyments but also had the most students stating positive enjoyments (“Slightly Enjoy” (4) and “Strongly Enjoy” (5)). The median for the groups of “No” and “Prefer not to answer”, is at “Slightly Enjoy” (4), with the median for the “Yes” group sits at “Neutral” (3), which is lower than the other two groups. About half of the students who stated that they got free/reduced lunch, either sat at “Neutral” (3) enjoyment or “Slightly Disliked” (2) for mathematics.

5.2.3 Student Confidence

RQ3: *Does exposure to the ActivityBot 360⁰ change students' confidence in STEM fields?*

Table 17. The Returned Wilcox P-Value for Pre/Post-Confidence

Confidence	Pre Post Pvalue
Robotics	7.413E-05
Electronics	6.100E-04
Computer Science	1.170E-05
Mathematics	0.1395

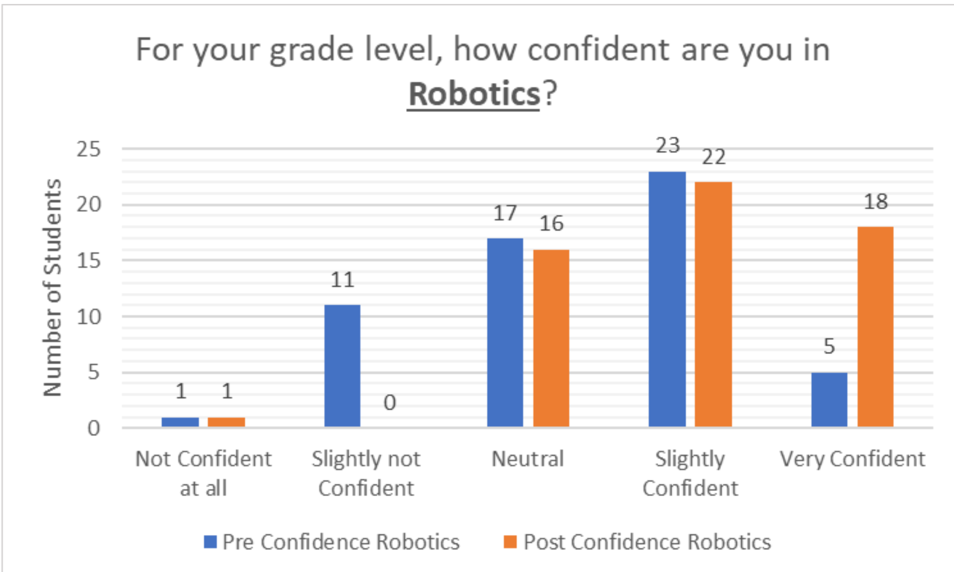

Figure 15. Frequency of Confidence Levels for Robotics

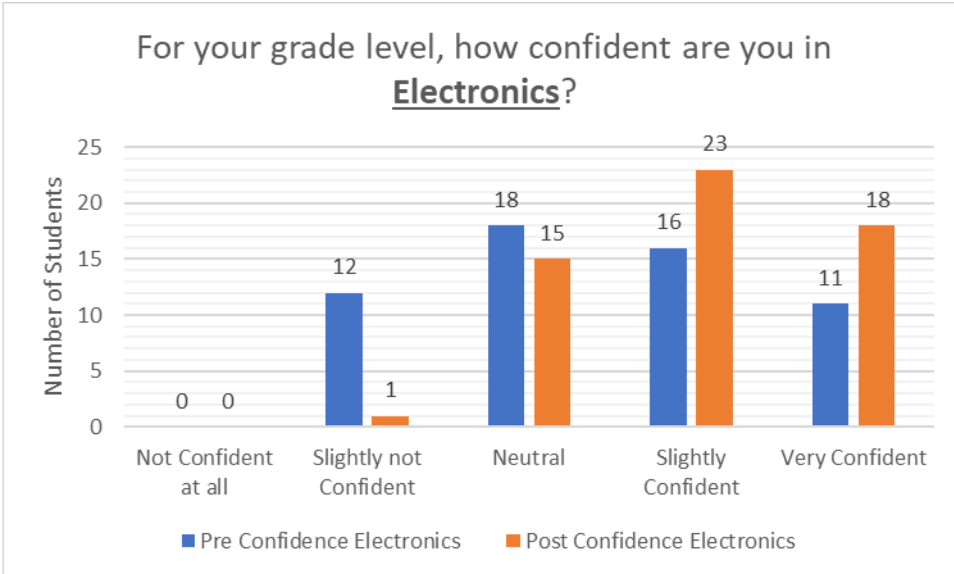

Figure 16. Frequency of Confidence Levels for Electronics

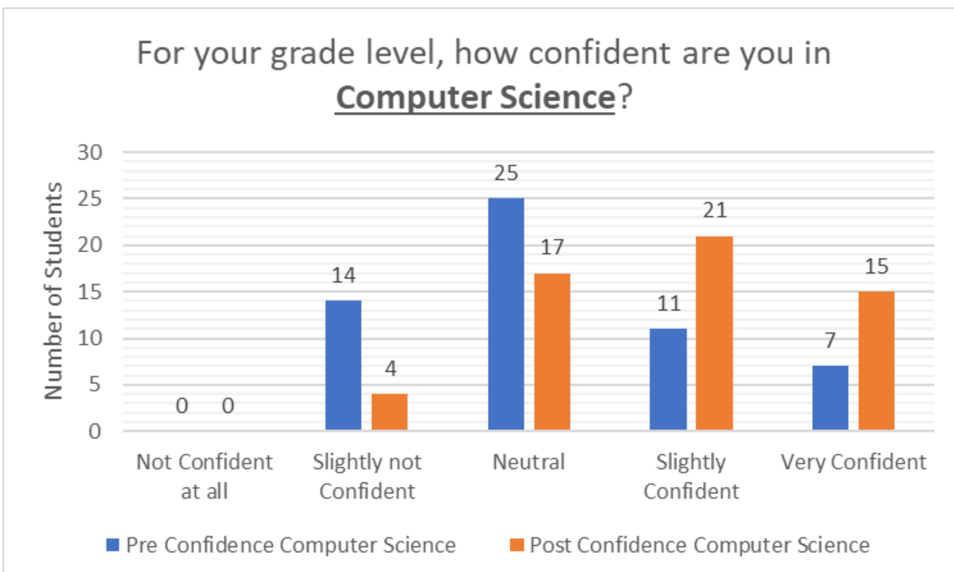

Figure 17. Frequency of Confidence Levels for Computer Science

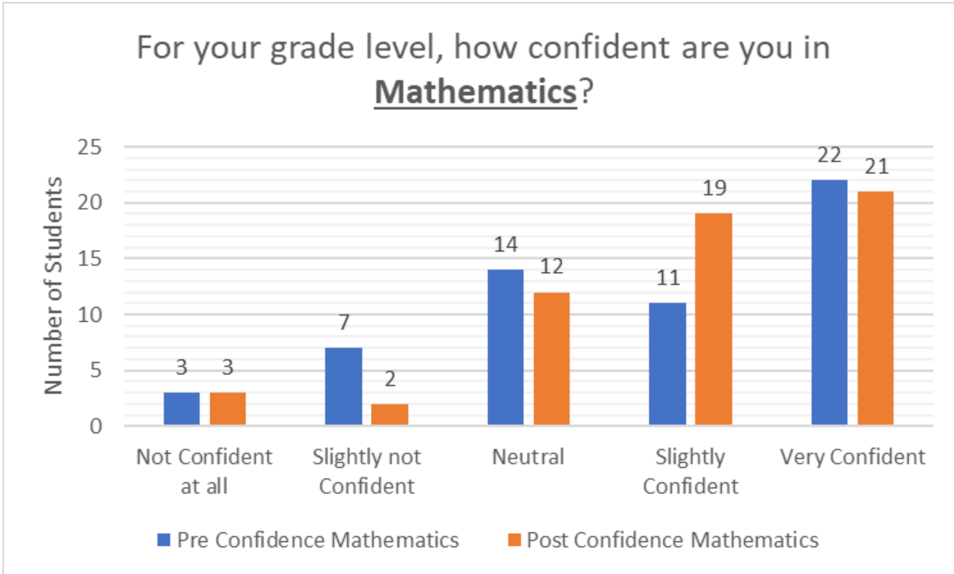

Figure 18. Frequency of Confidence Levels for Mathematics

NULL Hypothesis: There is no significant difference for the pre-confidence and post-confidence in the topics of Robotics, Electronics, Computer Science, and Mathematics for the two identical populations.

For testing this hypothesis, the pre and post-confidence datasets were passed into a Wilcox Test for all four of the topics. The resulting p-values, which are shown in Table 17, for this test are 7.41E-05, 6.10E-04, 1.17E-05, and 0.1395 for robotics, electronics, computer science, and mathematics respectively. The p-values for each topic, besides mathematics, are all less than the 0.05 significance level. Therefore, we can reject the NULL hypothesis for each topic, besides confidence in mathematics.

Shown in Figures 9, 21, and 23, confidence levels of 1 to 5 correspond to “Not Confident” at all to “Very Confident” respectively. Figures 20 and 22, are placed on a scale of the magnitude of how confidence changes. For example, if a student went from confidence level 4 (slightly confident) to 2 (slightly not confident) there would be a -2 difference in confidence.

Approximately half of the students’ initial stated confidence either sat at either “Neutral” (3) or “Slightly Confident” (4) for the topics of robotics, electronics, and computer science. The frequency of negative confidence responses (“Not Confident” (1) and “Slightly not Confident” (2)) decreased from 12 to 1 for robotics and electronics, and from 14 to 4 for computer science, which means confidence grew for all those topics. Shown in Figures 9, 21, and 23, the median confidence in these 3 topics grew by one confidence level from the time students took the pre-survey to the post-survey.

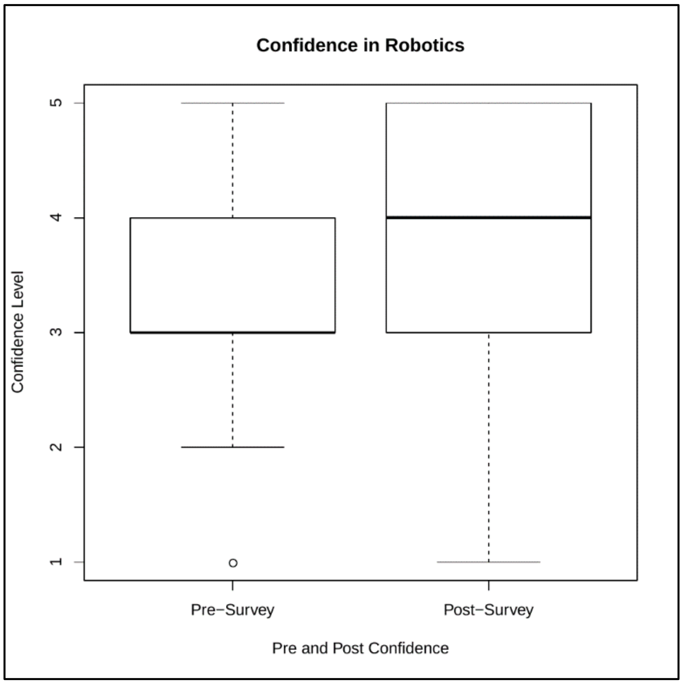

Figure 19. Differences of Pre and Post Survey Results for Confidence in Robotics

The demographical groups of students who either had or did not have experience with electronics and the groups of students who either had or did not have friends/family that worked in mathematics, had significantly different responses for the change in confidence with robotics.

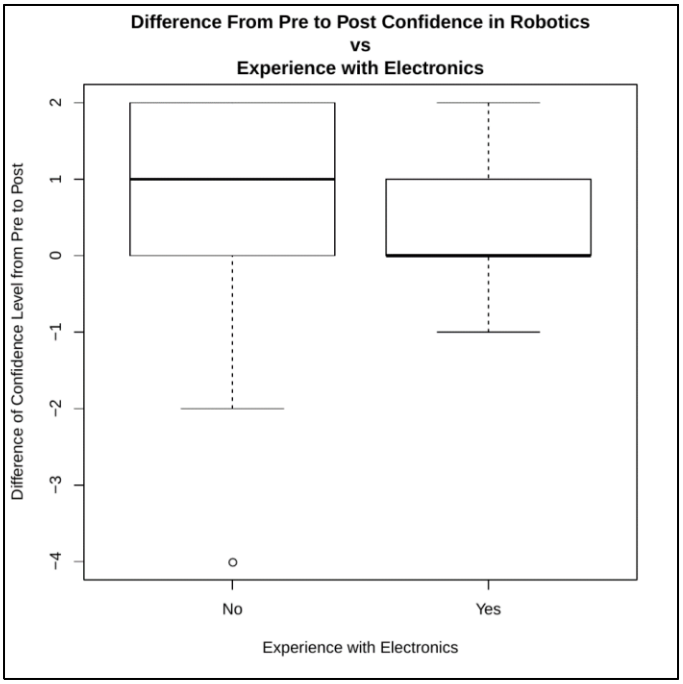

Figure 20. The Experience with Electronics Group Differences for the Change of Confidence in Robotics

Shown in Figure 20, with a p-value of 0.0423, students who did not have experience with electronics (33 out of 57 students) had a greater rise in confidence in robotics when compared to students who had experience with electronics (24 out of 57 students). It should be noted that initially only 33.33% of the students who did not have experience with electronics stated positive confidence (slightly and very confident). This grew to 63.64% of the students after the robotics intervention. 70.83% of the student who had experience with electronics initially stated that they had positive confidence. This grew to 79.17% of the students after the intervention. Students without experience had lower confidence levels when compared to experienced students, but the students without experience had a higher rise of confidence.

Even though the groups of students that have or do not have friends/family who work in mathematics returned a p-value of 0.0401, the data can be ignored since the groups have a population of 2 and 55 respectively.

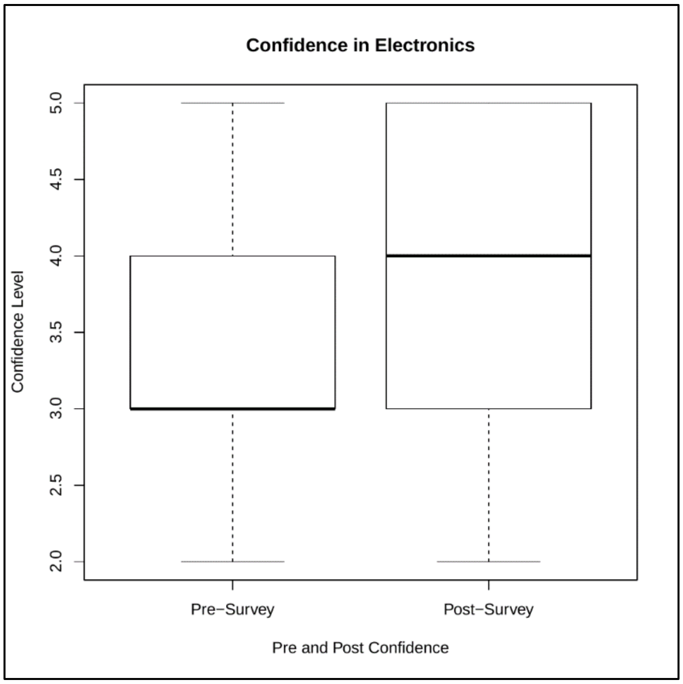

Figure 21. Differences of Pre and Post Survey Results for Confidence in Electronics

The demographical groups that were defined by the survey question, “Did you choose to take this STEM elective?” and the groups of students who either had or did not have friends/family that worked in mathematics, returned a p-value of less than the 0.05 significance level for the change in confidence in electronics.

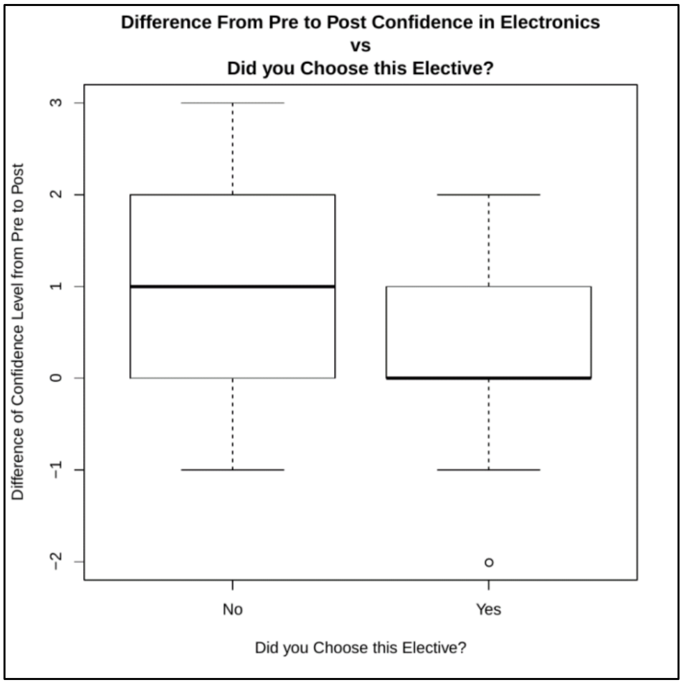

Figure 22. The Did You Choose this Elective Group Differences for the Change of Confidence in Electronics

Shown in Figure 22, with a p-value of 0.0426, students who did not choose this elective (20 out of 57 students) had a greater rise in confidence in electronics when compared to the group of students who did (37 out of 57 students). It should be noted that 30.00% of the students who did not choose this elective had a positive confidence initially. That positive confidence grew to 65.00% of the students. 56.76% of the students who did choose initially had a positive confidence, which rose to 75.68%.

Even though the groups of students that are defined by if they have friends/family who work in mathematics or not had a returned p-value of 0.0226, the data can be ignored since groups have a population of 2 and 55 respectively.

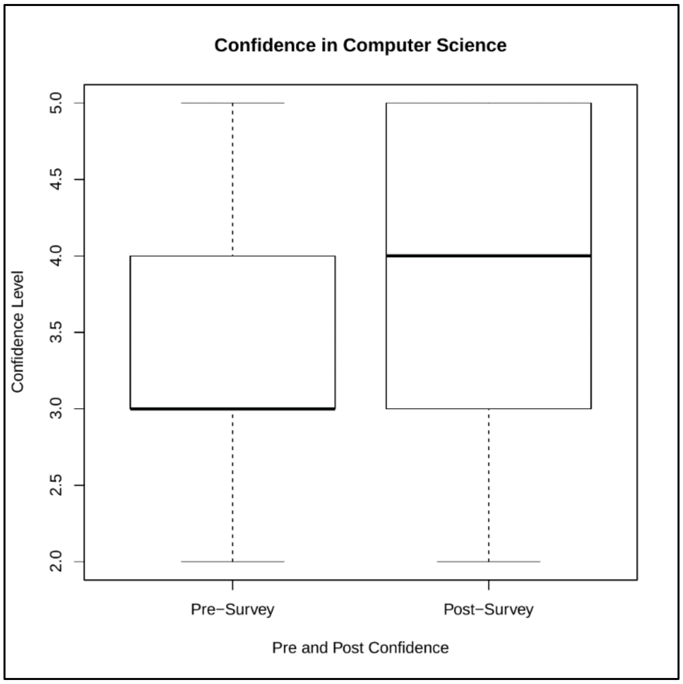

Figure 23. Differences of Pre and Post Survey Results for Confidence in Computer Science

Shown in Table 17, the returned p-value for the difference in pre to post-confidence in computer science is 0.0122. Even though there was a significant difference, all the demographical groups did not significantly differ (p-value > 0.05) for how their confidences changed.

When investigating if traditional demographical groups differed in confidences, it was found that each ethnic and economical group differed in their confidence in both computer science and mathematics for both the pre-survey and post-survey, however their change in confidence did not differ. Gender groups were found not to differ for all confidence topics.

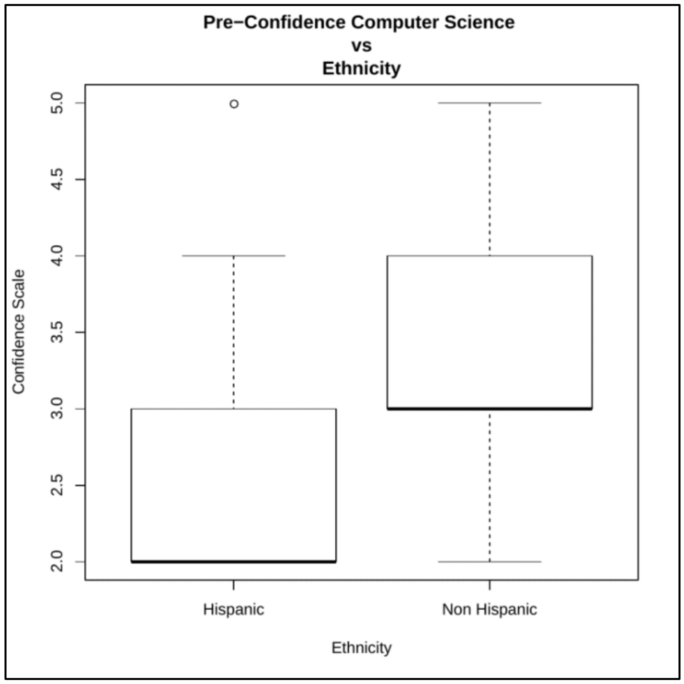

Figure 24. The Ethnic Group Differences for Pre-Confidence in Computer Science

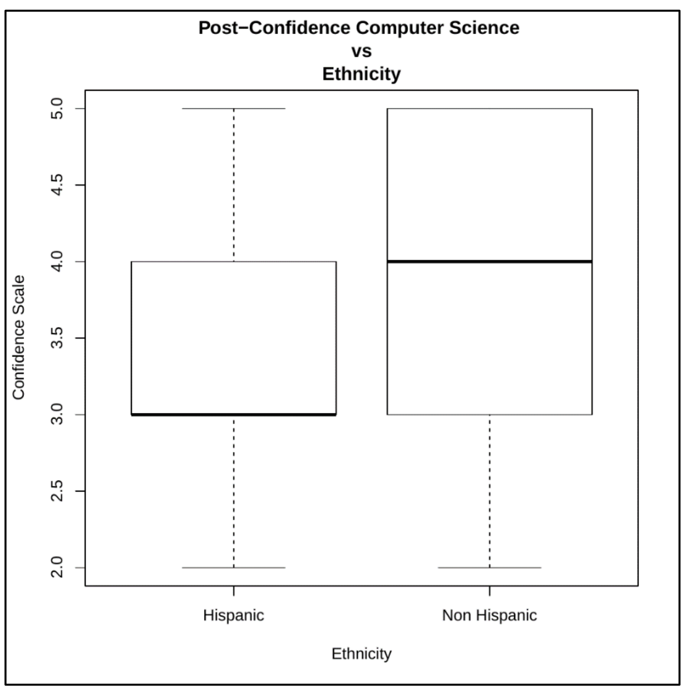

Figure 25. The Ethnic Group Differences for Post-Confidence in Computer Science

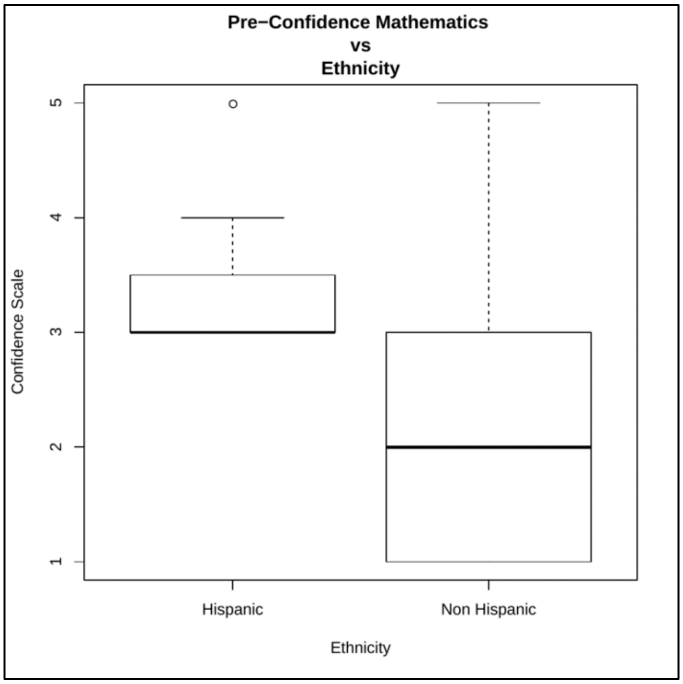

Figure 26. The Ethnic Group Differences for Pre-Confidence in Mathematics

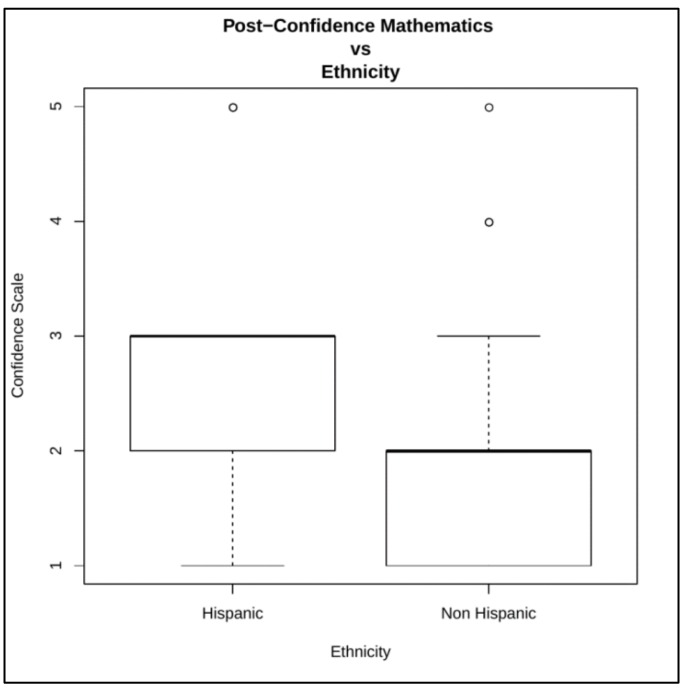

Figure 27. The Ethnic Group Differences for Post-Confidence in Mathematics

The two stated ethnic groups had a p-value of 0.0442 and 0.0286 for pre and post-confidence in computer science respectively. Shown in Figures 24 and 25, Hispanic students stated lower confidence in computer science when compared to non-Hispanics for both pre-survey and post-survey. For computer science, a p-value of 0.0006 and 0.0153 was returned for pre and post-confidence respectively. Shown in Figures 26 and 27, Hispanic students had a higher overall confidence in mathematics when compared to non-Hispanic students.

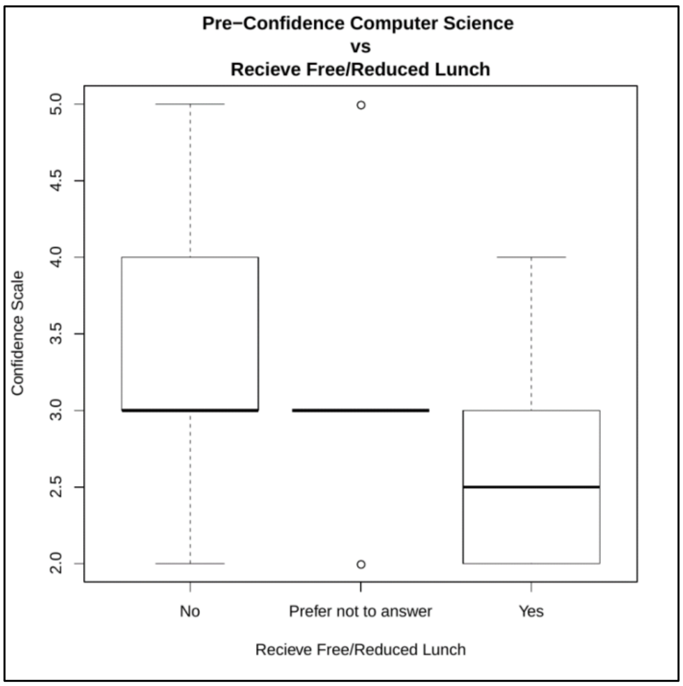

Figure 28. The Economical Group Differences for Pre-Confidence in Computer Science

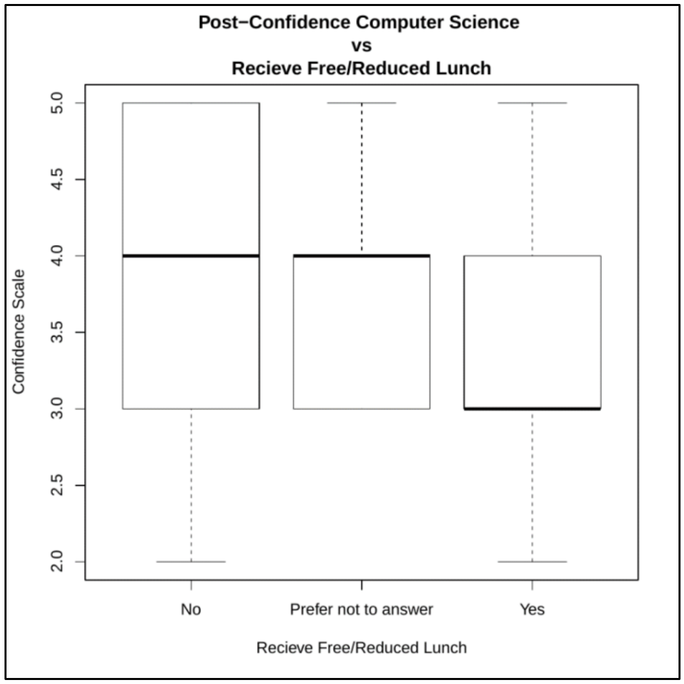

Figure 29. The Economical Group Differences for Post-Confidence in Computer Science

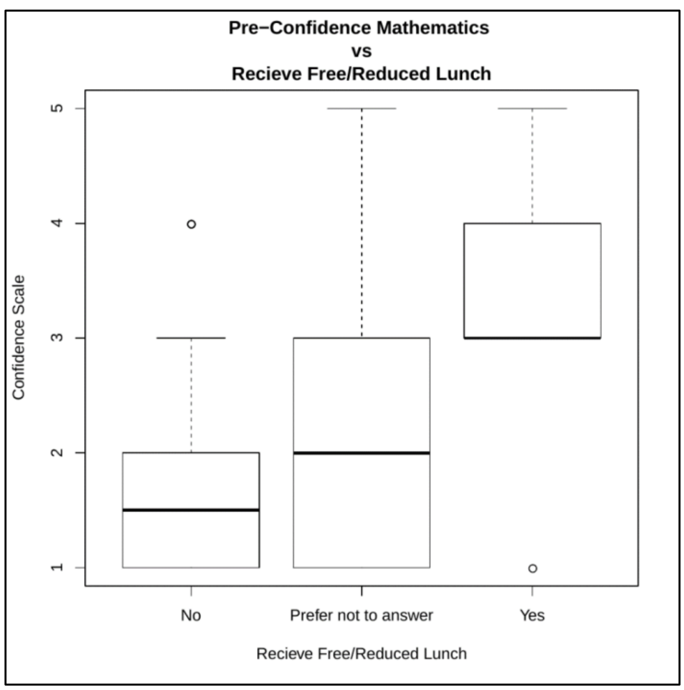

Figure 30. The Economical Group Differences for Pre-Confidence in Mathematics

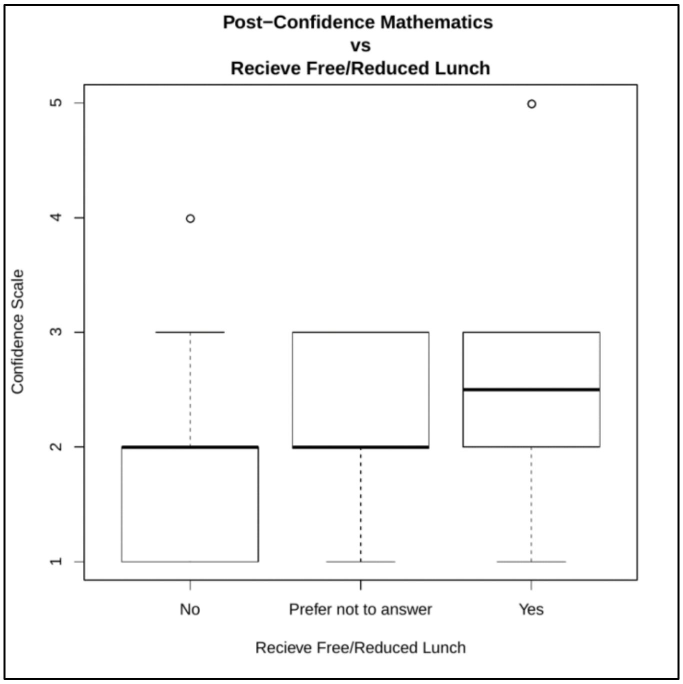

Figure 31. The Economical Group Differences for Post-Confidence in Mathematics

The different economical groups had a p-value of 0.013 and 0.017 returned for pre and post-confidence in computer science respectively. Shown in Figures 28 and 29, students who did not receive free/reduced lunch and students who preferred not to answer had the same medium pre and post-confidence. Students who did receive free/reduced lunch stated lower confidence in computer science when compared to the other two groups. For the topic of mathematics, p-values of 0.0006 and 0.0289 were returned for pre and post-confidence respectively. Shown in Figures 30 and 31, students who received free/reduced lunch had a higher confidence in mathematics compared to the other who groups.

5.2.4 Student Motivation

RQ4: *Does exposure to the ActivityBot 360⁰ change students' motivation to pursue a degree/career in STEM fields?*

Table 18. The returned Wilcox P-Values for Pre/Post-Motivation to Pursue a Degree/Career

Motivation	Pre Post Pvalue
Robotics	0.8761
Electronics	0.7718
Computer Science	0.4341
Mathematics	0.3035
STEM	0.3440

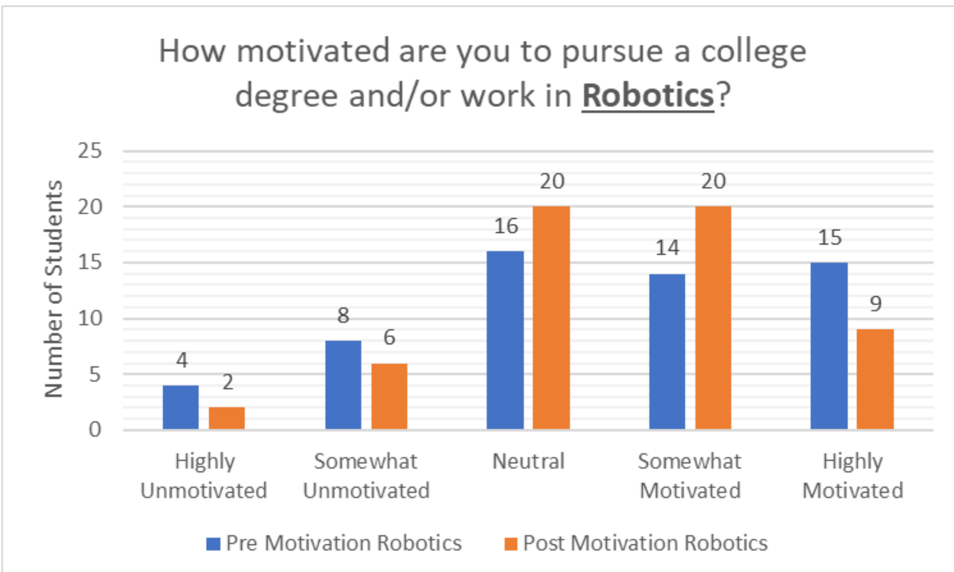

Figure 32. Frequency of Motivation Levels for Robotics

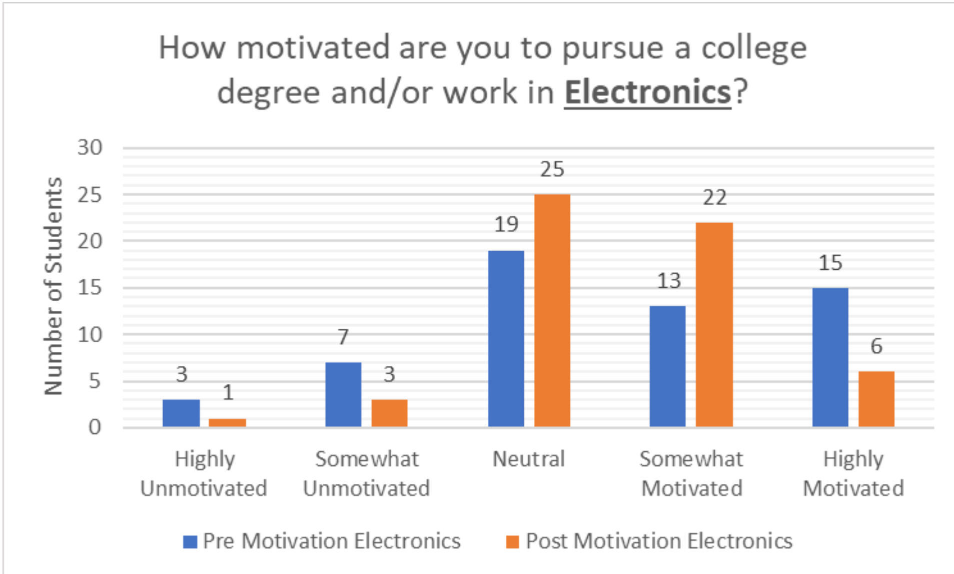

Figure 33. Frequency of Motivation Levels for Electronics

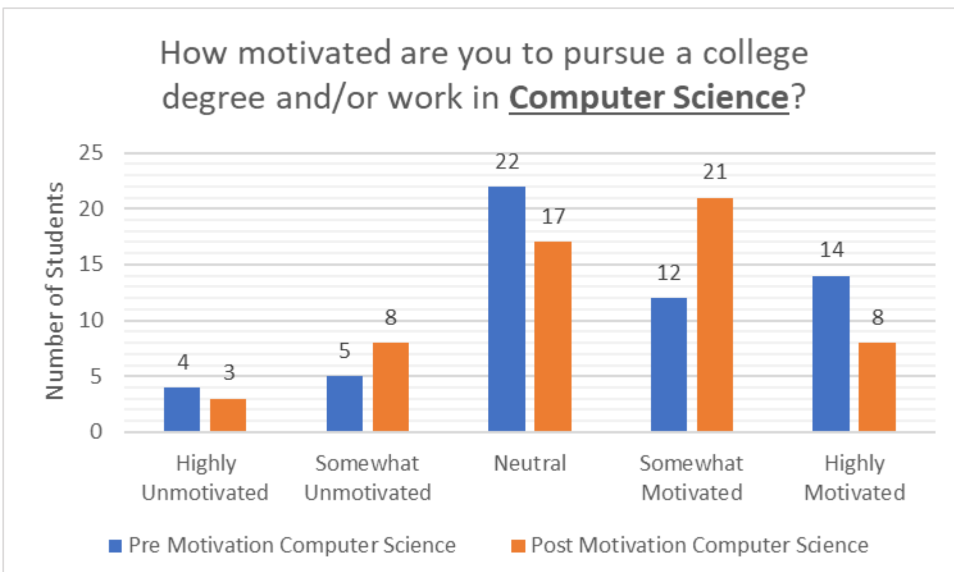

Figure 34. Frequency of Motivation Levels for Computer Science

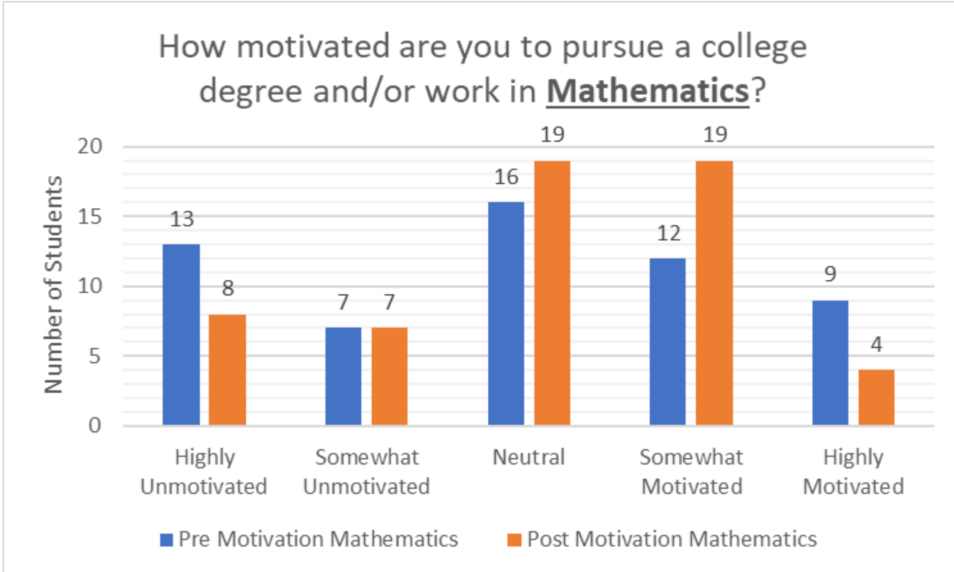

Figure 35. Frequency of Motivation Levels for Mathematics

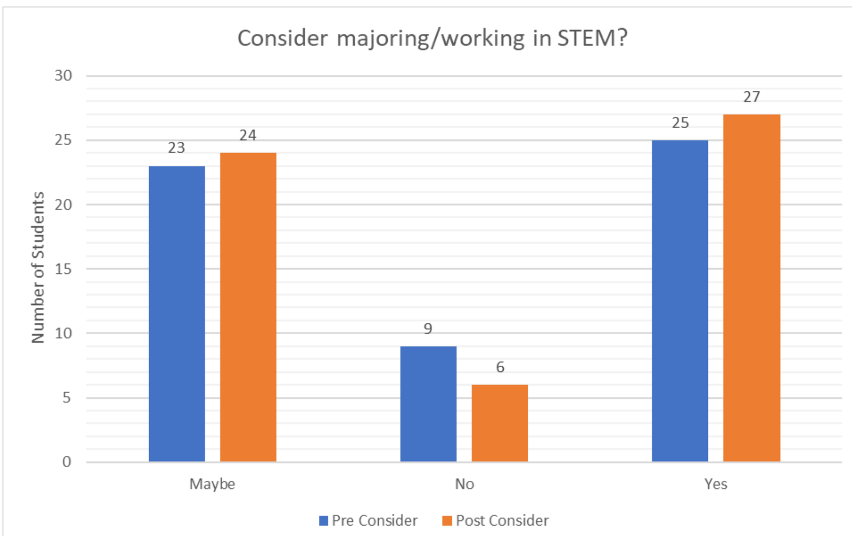

Figure 36. Motivation to Pursue a Degree/Career in a STEM

NULL Hypothesis: There are no significant differences for the pre and post-motivation to pursue a degree/career in the topics of robotics, electronics, computer science, mathematics, and/or STEM for the two identical populations.

Shown in Table 18, After applying the Wilcox Test, p-values of 0.8761, 0.7718, 0.4341, 0.3035, and 0.344 were returned for robotics, electronics, computer science, mathematics, and

STEM respectively. Since each value is greater than the 0.05 significance level, we can confirm this hypothesis, which means there are no significant differences from pre to post motivation.

For Figures 37, 38, 39, the motivation scale of 1 to 5 corresponds to the Likert motivation scale of “Highly Unmotivated” to “Highly Motivated” respectively.

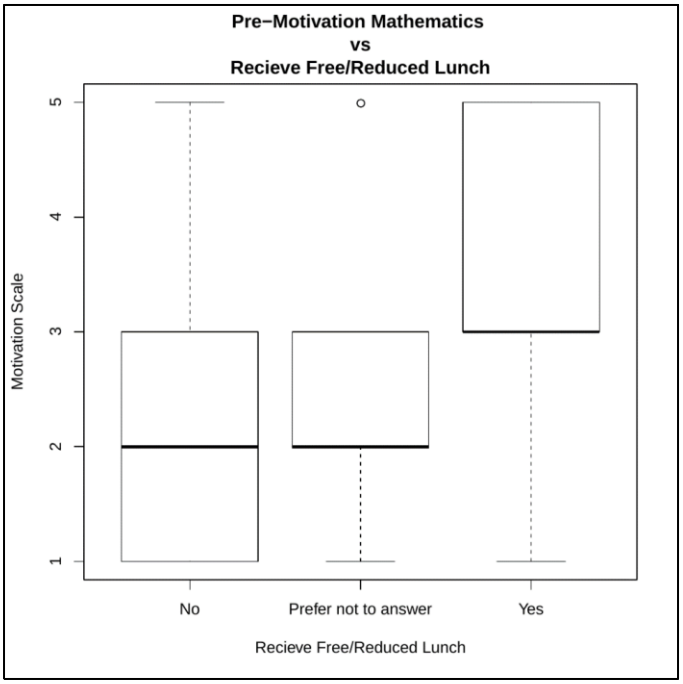

Figure 37. The Socio-Economic Group Differences for Pre-Motivation in Mathematics

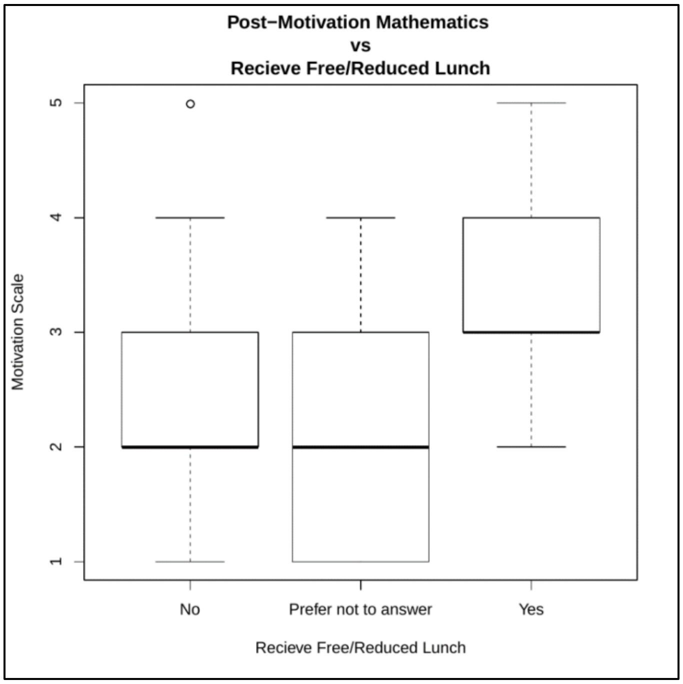

Figure 38. The Socio-Economic Group Differences for Post-Motivation in Mathematics

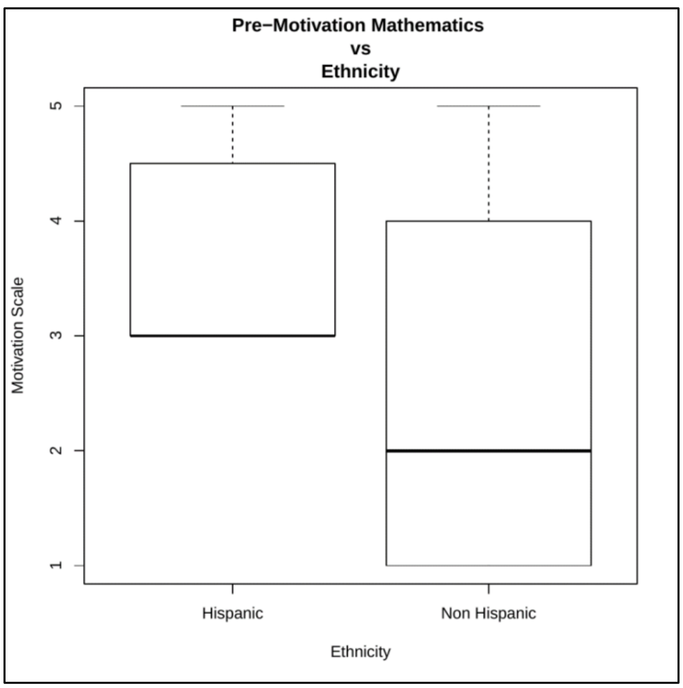

Figure 39. The Ethnic Group Differences for Pre-Motivation in Mathematics

For pre-motivation to pursue a degree/career in mathematics, a p-value of 0.0327 and 0.0132 were returned for economical and ethnic groups respectively. For post-motivation to pursue a degree/career in mathematics, a p-value of 0.0099 was returned for socio-economic groups. Shown in Figure 37 and 38, students who receive free/reduced lunch stated that they were the most motivated to pursue a degree/career in mathematics for both pre-survey and post-survey questions. Shown in Figure 39, Hispanic students had a higher overall motivation to pursue a degree/career in mathematics when compared to non-Hispanics. However, their post-motivation seemed to have non-significant differences between each ethnic groups (p-value of 0.1215, which is > 0.05). Gender groups were found not differ in their motivation when investigating how traditional demographic groups differed in their responses.

5.2.5 Student Knowledge

RQ5: *Does exposure to the ActivityBot 360 change students' knowledge in STEM fields?*

Table 19. The Returned Wilcox P-Values for Pre/Post-Quiz Question Grades

Question	Q1a	Q1b	Q1c	Q2	Q3	Q4	Q5	Q6	Q7x	Q7y	Q8
Pvalue	0.6078	1.000	0.9678	0.8568	0.0011	0.2835	0.2600	0.4429	0.965	0.8537	0.9811

Table 20. Results for the Part Identification Quiz Questions

Questions	Correct	Incorrect	No Answer
PreQ1a	53	2	2
PostQ1a	53	0	4
PreQ1b	48	7	2
PostQ1b	51	2	4
PreQ1c	47	8	2
PostQ1c	50	3	4
PreQ2	31	24	2
PostQ2	34	19	4
PreQ3	39	16	2
PostQ3	23	30	4
PreQ6	36	19	2
PostQ6	36	14	7

Table 21. Results for the Computational Thinking Quiz Questions

Questions	Correct	Incorrect	Not Sure
PreQ5	29	26	2
PostQ5	26	29	7
PreQ7x	19	20	18
PostQ7x	17	24	16
PreQ7y	19	20	18
PostQ7y	16	25	16
PreQ8	20	16	21
PostQ8	13	30	14

Table 22. Results for the Mathematical Quiz Question

Questions	Correct	Incorrect	Almost	Not Sure / No Answer
PreQ4	15	18	4	20
PostQ4	19	24	1	13

NULL Hypothesis: There are no significant differences for the pre and post-quiz question grades in the for the two identical populations.

For testing this hypothesis, each specific pre and post-quiz question grade were passed into a Wilcox Test. The resulting p-values are shown in Table 19. All p-values, besides Question 3, are greater than the 0.05 significance level. Therefore, we can confirm the NULL hypothesis for all quiz question grades besides Question 3, which returned a p-value of 0.0011.

Shown in Figure 20, Question 3 (Q3) corresponds to the question that asks students if an LED is in the correct orientation on an electrical schematic. The frequency of incorrect answers increased by 14 points from pre-quiz to post-quiz, even though students were exposed to the correct schematic and correct orientation during the ActivityBot 360º tutorials.

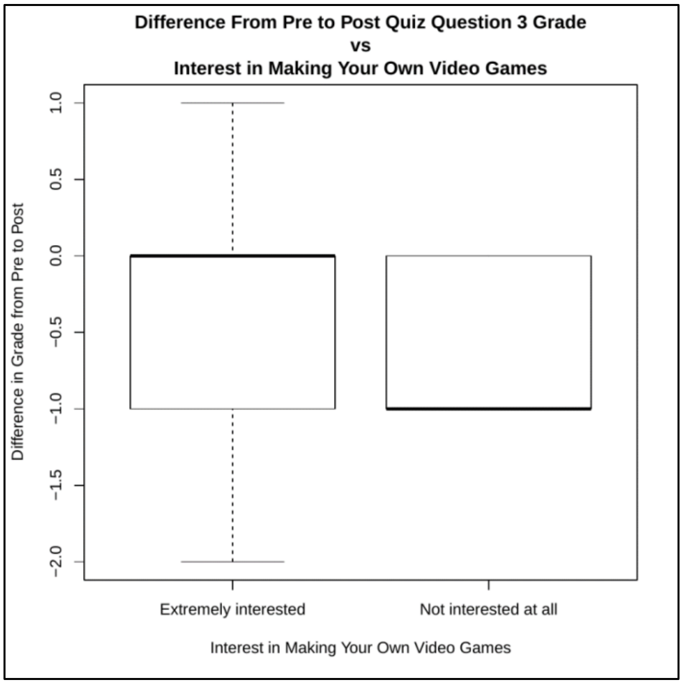

Figure 40. Interest in Making Video Game Group Differences for the Change of Grade in Quiz Question 3

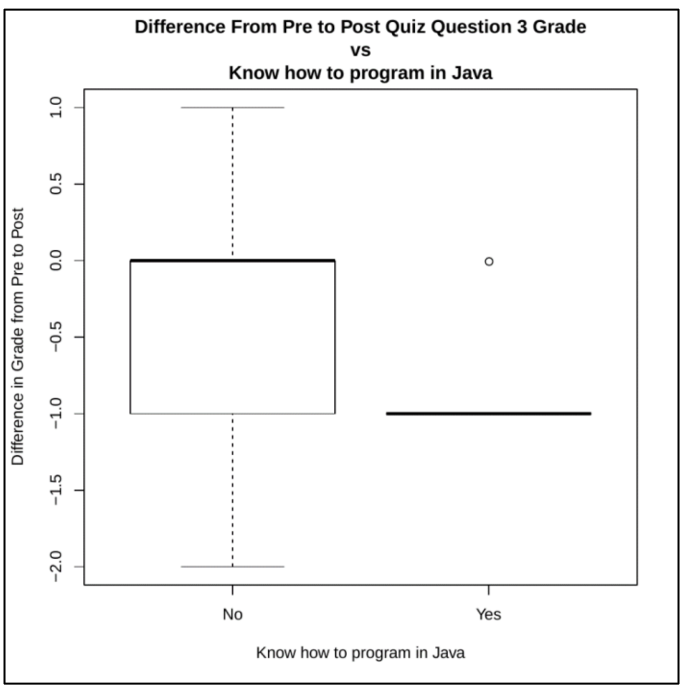

Figure 41. Experience with Java Group Differences for the Change of Grade in Quiz Question 3

For Question 3, the demographics that returned a p-value less than the 0.05 significance value were students who were or were not interested in making their own video games, students who do or do not have experience with programming in Java, and students who did or did not have experience with building RC cars.

For Question 3, a correct grade was represented with the number 2, incorrect grade was represented with the number 1, and no answer was represented with the number 0. In Figures 40 and 41 the difference scale from pre to post-grade shows three possible levels. These levels represent how the grade can change. A 0 indicates there was no change, 1 indicates that either a student went from “Incorrect” (1) to “Correct” (2) or went from “No Answer” (0) to “Incorrect” (1), -1 is the inverse of 1, and a -2 indicates that a student went from “Correct” (2) to “No Answer” (0). Shown in Table 20, a 2 students left no answer for pre-Question 3, while 4 students left no answer for post-Question 3, which should not have a significant effect in the results.

The returned p-value for the groups that were or were not interested in making their own video games was 0.0188. Shown in Figure 40, students who stated that they were interested in making their own video games (47 out of 57 students) did not change their grade on average. Students who stated that they were not interested in making their own video games (10 out of 57 students), on average, had a one-point drop. It should be noted that only 10 students stated that they were “Not interested at all” in making their own video games. Initially 6 out of those 10 students had correct answers. After the intervention, all 6 of those students went from correct to either incorrect or no answer.

The returned p-value for the groups that did or did not have experience with programming in Java was 0.0188. Shown in Figure 41, students who stated that they did not have experience with Java (51 out of 57 students), on average, did not have a change in their grade. 5 out of the 6 students who stated that they had experience with programming with Java went from a “Correct” (2) to an “Incorrect” (1). It should be noted that the total number of “Incorrect” answers increased by 14, which means 35.71% of the new “Incorrect” answers are from this group. The one student with no change in their answer was “Incorrect” for both pre and post quiz Question 3. It should be noted that students may have been answering this question randomly. When looking into the results, 33 out of the 57 students kept their results consistent for Question 3.

The returned p-value for the groups that did or did not have experience with building RC cars was 0.0130. Even though the p-value returned is less than the 0.05 significance level, this data can be ignored since the group who had experience with building RC cars totaled 4 students.

5.3 Follow-Up Question Results

Table 23. Frequency of Enjoyment Level in Topics Related to the Robotics Intervention

Like/Enjoy	Strongly Disliked	Somewhat Disliked	Indifferent	Somewhat Enjoyed	Strongly Enjoyed	No Answer
Programming with BlocklyProp	4	7	13	22	7	4
Costructing the Robot	0	3	10	15	25	4
Wiring up the robot	2	5	9	21	16	4
Robot Navigation	2	3	14	16	18	4
Playing with sensors	1	5	14	13	20	4

Shown in Table 23, the most positively enjoyed ("Strongly Enjoy" and "Somewhat Enjoy") topic listed was constructing the robot with 40 of the 57 students stating positive enjoyment, while only having 3 students state negative enjoyment ("Strongly Dislike" and "Somewhat Dislike"). The topic that was the most negatively enjoyed was programming with BlocklyProp, which had 11 out of 57 students stating negative enjoyment, while only having 29 students state positive enjoyment.

Table 24. Frequency of Motivation Level for Solving Problems in Topics Related to the Robotics Intervention

Motivation	Very Unmotivat	Somewhat Unmotivat	Indifferent	Somewhat Motivated	Very Motivated	No Answer
Programming with BlocklyProp	6	3	13	16	15	4
Constructing the Robot	2	4	9	18	20	4
Wiring Up the Robot	4	5	9	14	21	4
Robot Navigation	4	4	9	16	20	4
Sensor Problems	4	3	14	16	16	4

Shown in Table 24, the topic of constructing the robot had 38 out of 57 students state positive motivation ("Very Motivated" and "Somewhat Motivated") in solving problems, which is the largest topic compared to the others. Only 6 students stated that they had negative motivation ("Very Unmotivated" and "Somewhat Unmotivated") when constructing the robot. Negative motivation ranged from 6 to 9 for each topic.

Chapter 6 Future Works

Since this research was limited in time and human power, a lot could not be done for the betterment of this research. The research was limited to an online survey in an uncontrolled classroom. Even though the survey and quiz were reviewed and approved by a license teacher, they were not created by a professional statistician. Students did not always answer the questions, and some answered with contradictory answers.

This research can be improved with better evaluation tools and in class researchers, preferably in a week-long camp setting. Including middle school teachers who are trained in robotics, computer science, and/or electronics could also help improve students understanding of STEM. Even though our sample size was 57 students, it was conducted at a middle school in a small city in Oregon. Having this experiment take place in other areas with differing demographics would also help increase the precision of the answer this research is trying to conclude.

Chapter 7 Conclusion

While there were no significant correlations between exposure to the ActivityBot 360º and interest, enjoyment, and motivation to pursue a degree/career in STEM, there was a significant increase in confidence for 3 of the 4 different topics measured. This study showed that the exposure to the ActivityBot 360º, its tutorial, and instruction from a teacher, significantly increased the general confidence of Linus Pauling STE(A)M course students for the subjects of robotics, electronics, and computer science. It also showed that familiarizing students with parts and schematics can possibly create confusion, but further research needs to be conducted to confirm why less students got Question 3 correct.

This study also showed that different traditional demographic groups in the Linus Pauling STE(A)M course showed clear differences in choosing to take this elective, interest in this course, enjoyment in mathematics, and motivation to pursue a degree/career in mathematics. It showed that Hispanic students and students who receive free/reduced lunch have a generally lower confidence in computer science and have a generally higher confidence in mathematics when compared to their other respective groups.

The study also showed that students who had no experience with building or designing electronics had, on average, a higher rise in confidence in robotics than students who had experience. It also showed that students who did not choose this elective had, on average, a higher rise in confidence in electronics than students who did choose to take this elective.

7.1 Insights

Students who chose this elective typically stated that they had previous exposure to STEM topics. This combined with the other significant rise in confidence for inexperienced students in electronics shows how exposing inexperienced students to robotics and other STEM topics can grow their confidence significantly. Even if a student does not have any interest in STEM, if they have positive confidence, then they are more likely to believe that they could be someone who can pursue STEM. Without exposure to the technology and engineering fields in STEM, students may never gain confidence in these fields, will probably keep a fixed mindset about the fields, and may be discouraged from pursuing the ever-growing fields in STEM.

For Question 3, the tutorial may have caused confusion in which way an LED should be orientated, but since the majority of the students did not have prior experience with electronics, it is probable that students were answering randomly It should be noted that the teacher for this classroom is not trained in electronics, robotics, or computer science, but she is trained in mathematics. Which means if a student did not pick up the information about the LED orientation through the tutorial, then they probably did not pick up that information at all through the class. We believe that students who like and desire to create their own video games tend to also have interest in other technology and engineering topics. Likewise, it is probable that students disinterested in video games lacked interest in learning circuits, but it is more probable that they guessed randomly.

7.2 Recommendations for Educators

Even though this research showed that exposure to the ActivityBot 360º can increase students' confidence, it should be noted that for students to truly learn from this device there needs to be an instructor present who is trained in robotics, electronics, and/or computer science. Students can only learn so much from active learning on their own. With better trained teachers and an improved curriculum, students can more effectively learn to not only make the robot work but learn why it works as well.

While there is not an increase in motivation to pursue STEM fields as a result of the intervention suggests that students have already decided what they want to do by the 8th grade, which means earlier exposure could make a difference in shaping what they find interesting. However, the significant increase in confidence among those students without experience to technology and engineering fields suggests that exposure at any time is good and those who might not self-select into a STEM elective might have the most gain from it. In addition, making it mandatory for all students to take STEM CTE courses will also help improve equity for students who lack the resources to STEM exposure. Making sure that there is a 1 to 1 student to device (computer, robot, etc.) ratio can also be a way to make sure all students in this course are equally exposed to technology and engineering topics.

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Appendix A

Below shows the Parent Notification with an Opt-Out Process form in both English and Spanish.

Pre-CSPride – Programming Robots
Parent Notification with an Opt-Out Process

Your child is invited to take part in the Pre-CSPride – Programming Robots study conducted by Jennifer Parham-Mocello and Cathy Law of Oregon State University to help determine the quality of the Science, Technology, Engineering, and Mathematics (STEM) elective at Linus Pauling Middle School. Before you decide to allow your child to participate in this study, you should read this form and ask any questions you might have.

The purpose of this study is to evaluate the quality of the robotics programming portion of the STEM elective at Linus Pauling Middle School. This study will take place during regular classroom time. Participating children will be asked to provide demographic data and feedback about their interests in STEM. If your child does not participate in this study, they will complete their regularly scheduled school activities during the survey.

Participation in the Pre-CSPride study is not required, and you have one week to give the school the opt-out form for your child. You have the right to refuse your child's participation in, or to withdraw from, the study at any time without prejudice. Your child may choose not to participate at any time.

If findings of the study are published or presented to a professional audience, no personally identifying information will be released. Because it is not possible for us to know what studies may be a part of our future work, we ask that you give permission now for us to use data that we collect about you as part of this study without being contacted about each future study. Future use of these data will be limited to studies about STEM education.

There are no risks or harms expected for study participants.

Please contact the principal investigator, Jennifer Parham-Mocello, with any questions and concern parhammj@oregonstate.edu or (541) 737-8895.

If you DO NOT want your child to participate, please complete the information below and return the form to the teacher

I have read the information provided above. I have asked all the questions I have at this time.

☐ I DO NOT agree to have **my child participate in the CSPride – Programming Robots study**.

____
Name of Child

____
Name of Parent

___________________________________ ___________________
Signature of Parent Date

Pre-CSPride – Robots de Programación

Notificación a los padres con un proceso opt-out

Se invita a su hijo a participar en el estudio de pre-CSPride-robots de programación dirigido por Jennifer Parham-Mocello y Cathy Law de la Universidad Estatal de Oregon para ayudar a determinar la calidad de la electiva de Ciencia, Tecnología, Ingeniería y Matemáticas (STEM) en La escuela intermedia de Linus Pauling. Antes de que usted decida permitir que su niño participe en este estudio, usted debe leer este formulario y hacer cualquier pregunta que usted pueda tener.

El propósito de este estudio es evaluar la calidad de la porción de programación de robótica de la asignatura electiva de STEM en la escuela intermedia Linus Pauling. Este estudio se llevará a cabo durante el horario regular del aula. Se pedirá a los niños participantes que proporcionen datos demográficos y retroalimentación sobre sus intereses en STEM. Si su hijo no participa en este estudio, ellos completarán sus actividades escolares regularmente programadas durante la encuesta.

La participación en el estudio Pre-CSPride no es requerida, y usted tiene una semana para darle a la escuela el formulario de opt-out para su hijo. Usted tiene el derecho de rehusar la participación de su hijo/a en el estudio en cualquier momento sin prejuicios. Su hijo puede optar por no participar en ningún momento.

Si las conclusiones del estudio se publican o se presentan a una audiencia profesional, no se divulgará ninguna información personalmente de identificación. Debido a que no es posible que sepamos qué estudios pueden ser parte de nuestro trabajo futuro, le pedimos que nos dé permiso ahora para que usemos los datos que recopilamos sobre usted como parte de este estudio sin que nos contacten sobre cada estudio futuro. El uso futuro de estos datos se limitará a los estudios sobre educación STEM.

No hay riesgos o daños esperados para los participantes del estudio.

Por favor, póngase en contacto con la investigadora principal, Jennifer Parham-Mocello, con cualquier pregunta y preocupación parhammj@oregonstate.edu o (541) 737-8895.

Si usted NO QUIERE que su hijo/a participe, por favor complete la siguiente información y devuelva el formulario al maestro/a

He leído la información proporcionada anteriormente. He hecho todas las preguntas que tengo en este momento.

☐ NO **ACEPTO** que **mi hijo participe en el CSPride - Un programa electivo de informática de la escuela media estudiar** en la Escuela Intermedia Linus Pauling.

____
Nombre del niño

____
Nombre del Padre

____________________________________ ____________________
Firma del padre Fecha

Appendix B

Below shows the student assent form and the English Pre-Survey.

English ▼

General

ASSENT FORM
Project Title: CSPride - A Middle School Computer Science Elective Program
Principal Investgator: Jennifer Parham-Mocello
Co-Investgator(s): Catherine Law

We are asking you whether you want to be in the research study. Research is a way to test new ideas and learn new things. You do not have to be in the study if you do not want to. You can say Yes or No. If you say yes now, you can change your mind later. Your decision to participate or not participate in this research will not impact your grade or relationship with your teacher.

Ask questions if there is something that you do not understand. After all of your questions have been answered, you can decide if you want to be in this study or not.

This study is about creating a better Science, Technology, Engineering, and Mathematics (STEM) elective program at Linus Pauling Middle School.

We are asking you if you want to be in this study because you are currently a student at Linus Pauling Middle School in the STEM elective.

If you take part in this study, we will ask you to fill out a survey and complete several technical task about the STEM elective. This survey should take approximately 10 minutes and the technical tasks may take up to 30 minutes.

We can't guarantee the confidentiality of the information collected online. Confidentiality will be maintained to the extent of the technology being used. Information collected from you in this study may be used or distributed for future research. Future use of information will be limited to STEM education research.

Some good things that might happen to you, if you are in this study, are getting to help create a better STEM program for your school and making the electives better. We are not sure that these things will happen. We might also find out things that will help other students some day.

We will write a report when the study is over, but we will not use your name in the report.

If you have questions about this study, please contact Jennifer Parham-Mocello at parhammj@oregonstate.edu. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Human Research Protection Program (HRPP) office, at (541) 737-8008 or by email at IRB@oregonstate.edu.

If you want to be in the study, please select "Yes, I want to be in the study" or "No, I don't want to be in the study".

- ○ Yes, I want to be in the study
- ○ No, I do not want to be in the study

First and Last Name

Gender

- ○ Male
- ○ Female
- ○ Other

Do you receive free and reduced lunch?

- ○

Yes

- No
- Prefer not to answer

Ethnicity:

- Hispanic
- Non Hispanic

Which elementary school did you attend?

- Garfield Elementary
- Lincoln Elementary
- Adams Elementary
- Jefferson Elementary
- Other

Which school did you attend that is not on the list above? Please state it below.

Elective

Did you choose to take this STEM elective?

- Yes
- No

Please state why you chose this STEM elective.

Please state why you are in this STEM elective.

How interested are you in this STEM elective?

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not interested at all

Have you attended any Science, Technology, Engineering, and/or Mathematics (STEM) related courses or camps other than this course? (Such as coding classes, robotics camp, etc.)

- Yes
- No

Please list the courses or camps you have already taken.

Rate your interest in the following STEM topics:

	Not interested at all	Extremely interested
Using a 3D Printer		
Programming Robots		
Making Your Own Webpage		
Making Your Own Apps		
Making Your Own Video Games		
Designing 3D Shapes on Computers		
Writing Your Own Computer Programs		
Making Your Own Animations		
Designing Your Dream Home		
Making Things Move with Motors		
Creating Art on Computers		

List any STEM electives not mentioned above that interest you?

Programming

Do you have any experience with programming or computer science? (Such as programming video games, Code.org, Scratch, Lego Robotics, programming Ardiuno/RaspberryPi, creating a web page, etc.)

- Yes

- No

Please list which programming languages you have used.

- Scratch
- Python
- HTML
- C/C++
- Swift or Swift Blocks
- Sphero Block
- Block (Scratch, Lego Robotics, Alice, Snap, etc.)
- Blocklyprop
- FTC Blocks
- Java/Java-Script
- Programming Lego Mindstorm
- Ruby
- IOS App Programming
- Android App Programming
- Other

Please state which programming languages you have used.

If you have done any programming projects, then please list some of your projects.

Do you have any friends or family who know how to program?

- Yes
- No
- Not sure

Robotics

Do you have any experience with building and/or programming robots?

- Yes
- No

Please select what you have experience with below.

- ☐ Lego Robots
- ☐ Cozmo
- ☐ Parallax ActivityBot
- ☐ Building/Programming random robots in the class room
- ☐ Other

Please write down other experience with robots you have.

Do you have any family or friends who build and/or program robots?

- ○ Yes
- ○ No
- ○ Not sure

Electronics

Do you have any experience with building and/or designing electronics? (Such as working with Arduino, building RC car, bread boarding circuits, etc.)

- ○ Yes
- ○ No

Please select what you have experience with.

- ☐ Arduino
- ☐ Basic Bread Boarding
- ☐ Audio Circuits
- ☐ Electronics Kits
- ☐ Building circuits that move motors
- ☐ Other

Please list any other experiences you had with building and/or designing electronics.

Do you have any family or friends who build and/or design their own electronics?

- ○ Yes
- ○ No
- ○ Not sure

What is your future?

How much do you enjoy these fields?

	Strongly Dislike	Slightly Dislike	Neutral	Slightly Enjoy	Strongly Enjoy	Not Sure
Robotics	○	○	○	○	○	○
Electronics	○	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○	○
Mathematics	○	○	○	○	○	○

How motivated are you to pursue a college degree and/or work in these field in the future?

	Highly Unmotivated	Somewhat Unmotivated	Neutral	Somewhat Motivated	Highly Motivated
Robotics	○	○	○	○	○
Electronics	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○
Mathematics	○	○	○	○	○

For your grade level, how confident are you in each field?

	Not Confident at all	Slightly not Confident	Neutral	Slightly Confident	Very Confident
Robotics	○	○	○	○	○
Electronics	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○
Mathematics	○	○	○	○	○

What do you like or dislike about Robotics?

What do you like or dislike about Electronics?

What do you like or dislike about Programming or Computer Science?

What do you like or dislike about Mathematics?

Would you ever consider majoring and/or working in a STEM (Science, Technology, Engineering, and/or Mathematics) oriented field?

- Yes
- No
- Maybe

Please list which STEM fields you are most interested in majoring and/or working in.

Please list the reason(s) you are not interested in majoring and/or working in STEM fields.

Work

Do you have any friends or family who work in a STEM (Science, Technology, Engineering, and/or Mathematics) oriented field?

- Yes
- No
- Not sure

Please select which fields they work in.

- Electrical Engineering
- Computer Science
- Robotics
- Mechanical Engineering
- Chemical Engineering
- Civil Engineering
- Environmental Engineering
- Mathamatics
- Other

Please list which other field they are in.

Block 1

Match each image with its corresponding part name.

A

B

C

Servo Motor:

▾

LED:

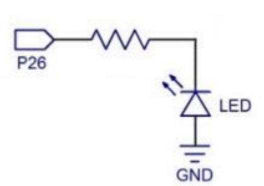
Resistor:

Block 2

What is the symbol above?

- Capacitor
- Resistor
- Inductor
- Servo Motor

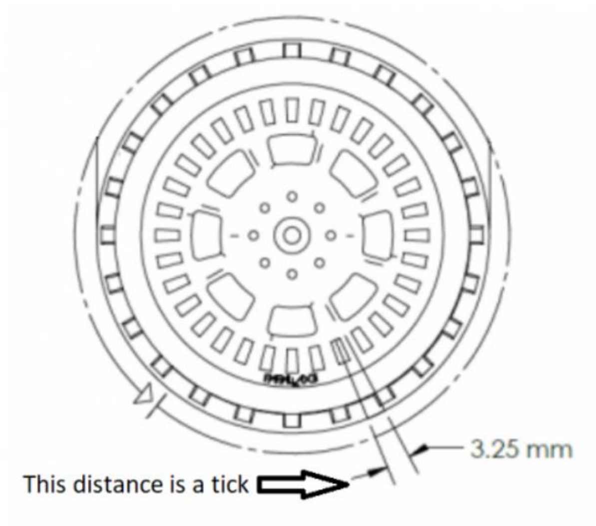
Block 3



Above shows a circuit diagram with an LED. Is the LED placed in the correct orientation?

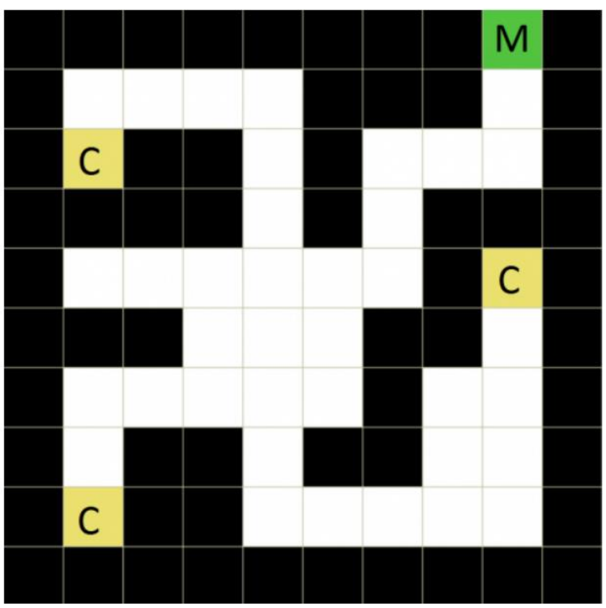
- Yes
- No

Block 4

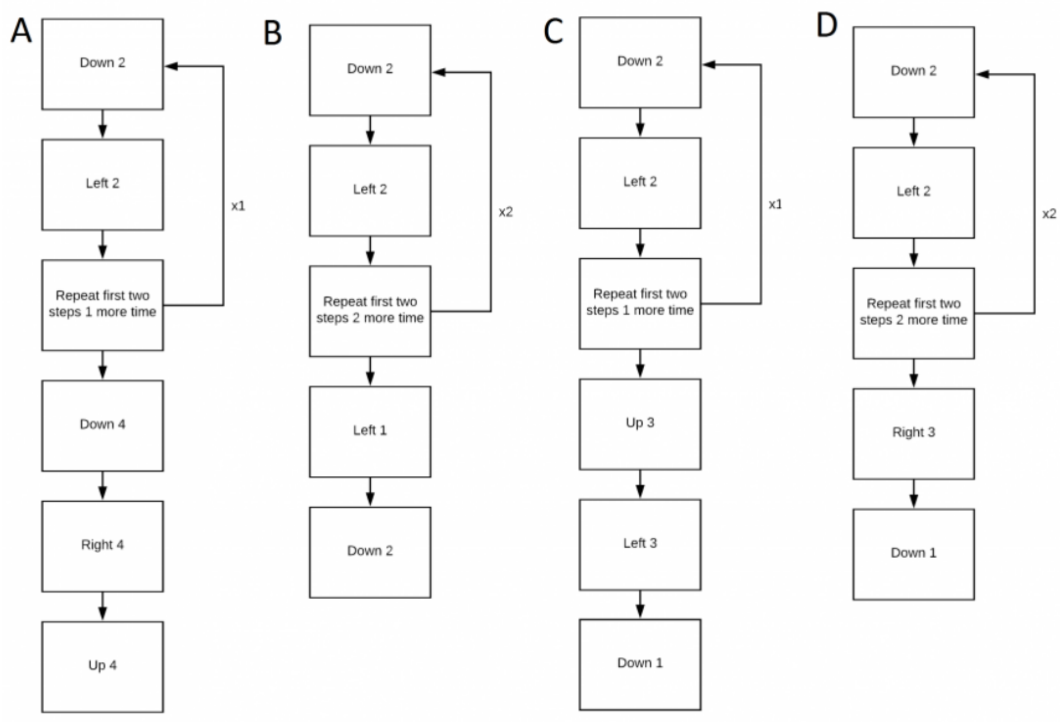


If a full rotation of a robot's wheel is 100 ticks, and the wheel will rotate 3.25 millimeters (mm) per tick, how many millimeters (mm) will the wheel go if it rotates 2.5 full rotations? Note: The image is not to scale.

Block 5



Maze Instructions

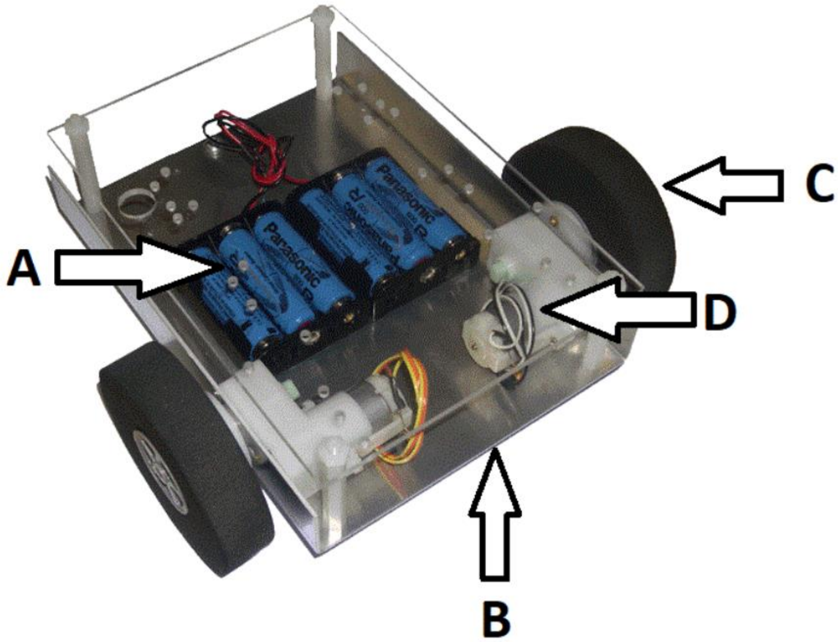


Above is a maze with a mouse (shown by the M) and some cheese (shown by the C). The mouse wants to get to one of the cheeses but has a bad memory. Choose the simplest set of instructions to help the mouse get to the cheese. Assume you can communicate with the mouse.

▼

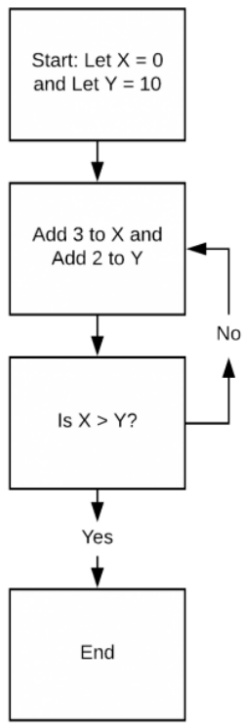
Block 6

Below shows an image of a robot. Click the letter that is pointing to the chassis.



Block 7

Below shows a logical flow chart. What are the values of X and Y by the End of the flowchart?

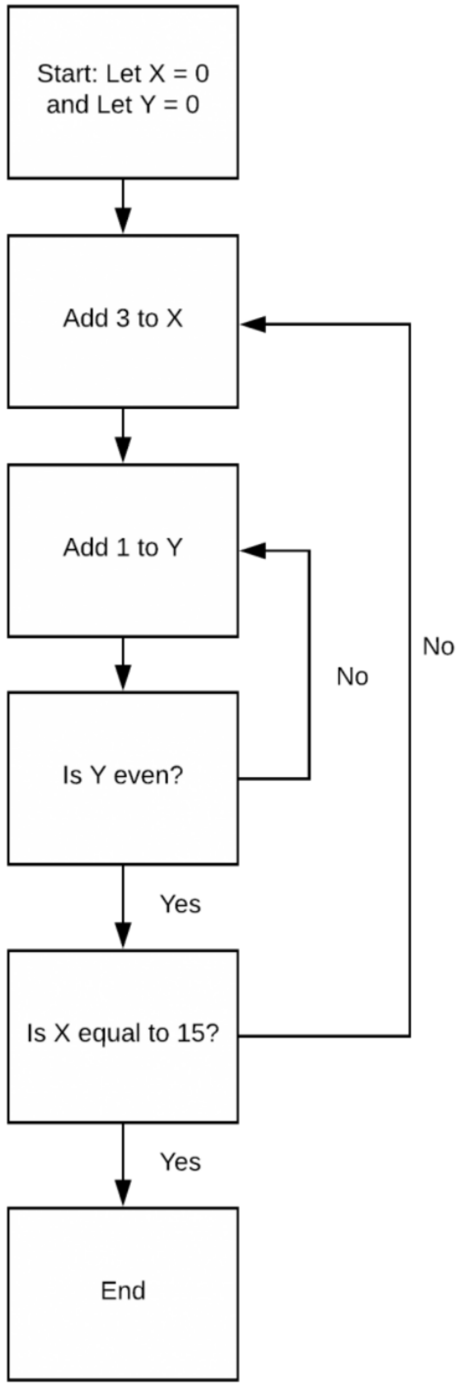


What is the value of X at the End of the flowchart?

What is the value of Y at the End of the flowchart?

Block 8

Below shows a logical flow chart. What is the value of Y by the End of the flowchart?



Start: Let X = 0 and Let Y = 0
Add 3 to X
Add 1 to Y
Is Y even?
No
No
Yes
Is X equal to 15?
Yes
End

What is the value of Y by the End of the flowchart?

Appendix C

Below shows the student assent form and the English Post-Survey.

English ▼

Assent

ASSENT FORM
Project Title: CSPride - A Middle School Computer Science Elective Program
Principal Investgator: Jennifer Parham-Mocello
Co-Investgator(s): **Maggie Niess**

We are asking you whether you want to be in the research study. Research is a way to test new ideas and learn new things. You do not have to be in the study if you do not want to. You can say Yes or No. If you say yes now, you can change your mind later. Your decision to participate or not participate in this research will not impact your grade or relationship with your teacher.

Ask questions if there is something that you do not understand. After all of your questions have been answered, you can decide if you want to be in this study or not.

This study is about creating a better Science, Technology, Engineering, and Mathematics (STEM) elective program at Linus Pauling Middle School.

We are asking you if you want to be in this study because you are currently a student at Linus Pauling Middle School in the STEM elective.

If you take part in this study, we will ask you to fill out a survey and complete several technical task about the STEM elective. This survey should take approximately 10 minutes and the technical tasks may take up to 30 minutes.

We can't guarantee the confidentiality of the information collected online. Confidentiality will be maintained to the extent of the technology being used. Information collected from you in this study may be used or distributed for future research. Future use of information will be limited to STEM education research.

Some good things that might happen to you, if you are in this study, are getting to help create a better STEM program for your school and making the electives better. We are not sure that these things will happen. We might also find out things that will help other students some day.

We will write a report when the study is over, but we will not use your name in the report.

If you have questions about this study, please contact Jennifer Parham-Mocello at parhammj@oregonstate.edu. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Human Research Protection Program (HRPP) office, at (541) 737-8008 or by email at IRB@oregonstate.edu.

If you want to be in the study, please select "Yes, I want to be in the study" or "No, I don't want to be in the study".

- ○ Yes, I want to be in the study
- ○ No, I do not want to be in the study

General

First and Last Name

____

How interested were you in this STEM elective?

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not interested at all

After Using ActivityBot

After using the ActivityBot, how much do you enjoy these fields?

	Strongly Dislike	Slightly Dislike	Neutral	Slightly Enjoy	Strongly Enjoy	Not Sure
Robotics	○	○	○	○	○	○
Electronics	○	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○	○
Mathematics	○	○	○	○	○	○

After using the ActivityBot, how motivated are you to pursue a college degree and/or work in these field in the future?

	Highly Unmotivated	Somewhat Unmotivated	Neutral	Somewhat Motivated	Highly Motivated
Robotics	○	○	○	○	○
Electronics	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○
Mathematics	○	○	○	○	○

After using the ActivityBot, how confident are you in each field for your grade level?

	Not Confident at all	Slightly not Confident	Neutral	Slightly Confident	Very Confident
Robotics	○	○	○	○	○
Electronics	○	○	○	○	○
Programming / Computer Science	○	○	○	○	○
Mathematics	○	○	○	○	○

Would you ever consider majoring and/or working in a STEM (Science, Technology, Engineering, and/or Mathematics) oriented field?

- Yes
- No
- Maybe

Please list which STEM fields you are most interested in majoring and/or working in.

Please list the reason(s) you are not interested in majoring and/or working in STEM fields.

ActivityBot

While using the ActivityBot how much did you enjoy each topic?

	Strongly disklike	Somewhat disklike	Indifferent	Somewhat Enjoy	Strongly Enjoy
Programming with BlocklyProp	○	○	○	○	○
Constructing the robot	○	○	○	○	○
Wiring up the robot	○	○	○	○	○
Robot navigation	○	○	○	○	○
Playing with sensors	○	○	○	○	○

When running into problems with the ActivityBot, how motivated were you to solve those problems?

	Very Unmotivated	Somewhat Unmotivated	Indifferent	Somewhat Motivated	Very Motivated
Programming with BlocklyProp	○	○	○	○	○
Constructing the robot	○	○	○	○	○
Wiring up the robot	○	○	○	○	○
Robot navigation	○	○	○	○	○
Sensor problems	○	○	○	○	○

Were you able to solve most problems with the ActivityBot?

- ○ Yes
- ○ No
- ○ I had no problems with the ActivityBot

Block 1

Match each image with its corresponding part name.

A

B

C

Servo Motor:

▾

LED:

▾

Resistor:

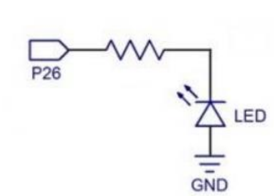
▾

Block 2

What is the symbol above?

- Capacitor
- Resistor
- Inductor
- Servo Motor

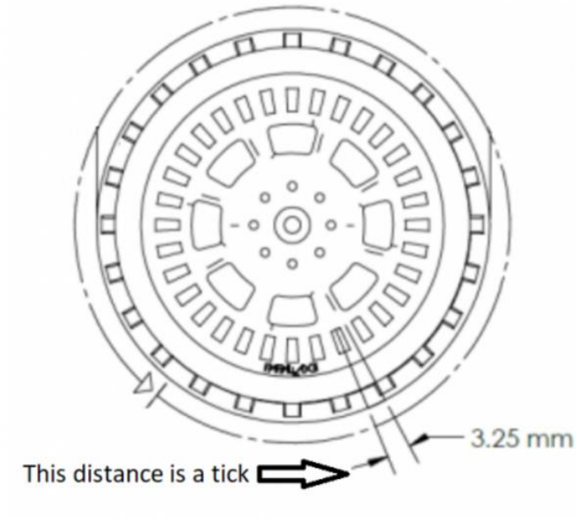
Block 3



Above shows a circuit diagram with an LED. Is the LED placed in the correct orientation?

- Yes
- No

Block 4



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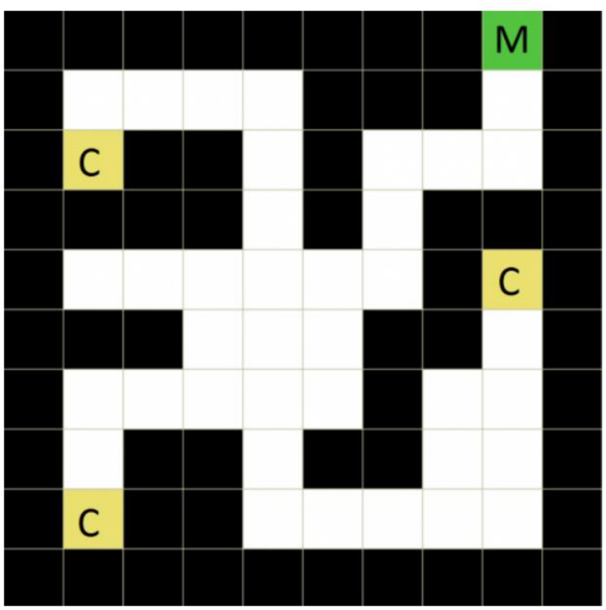
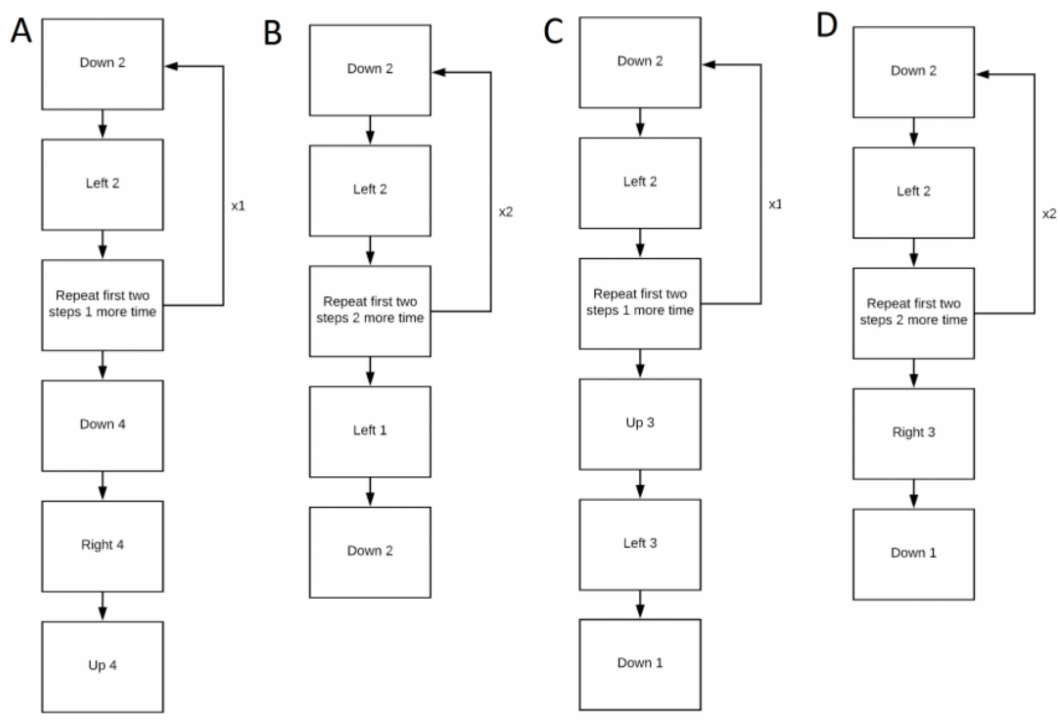


Options in English



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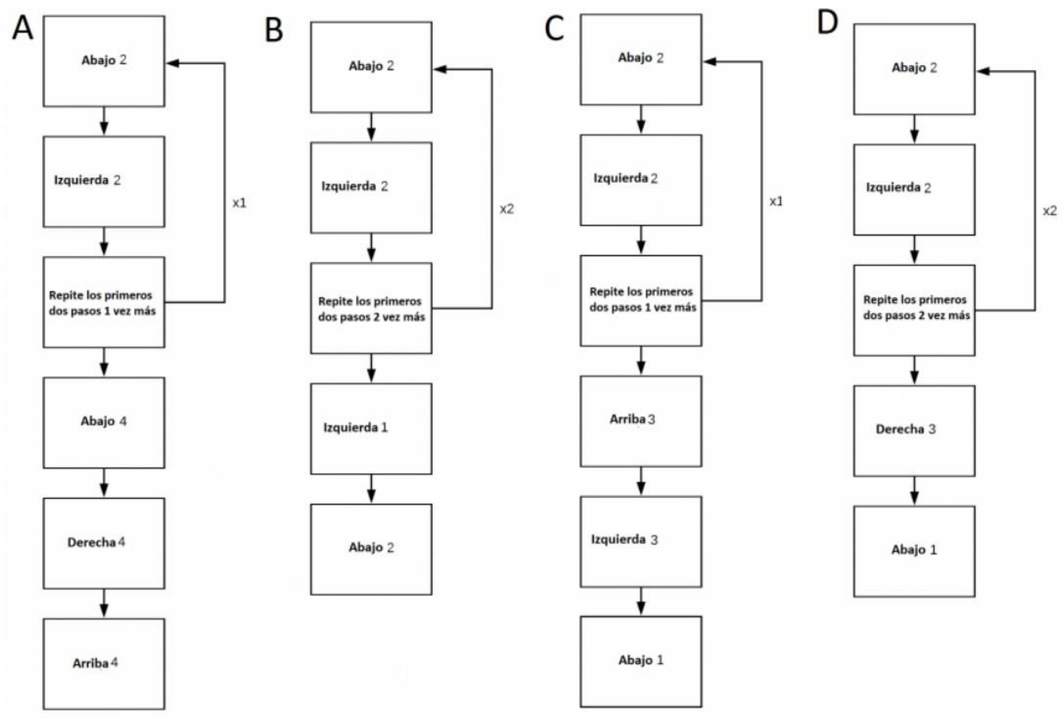
Options in Spanish:



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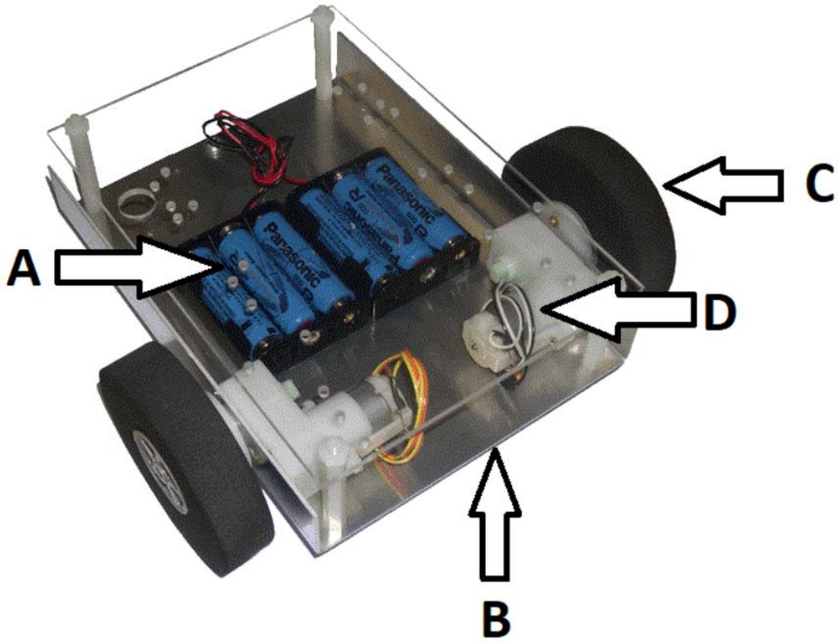

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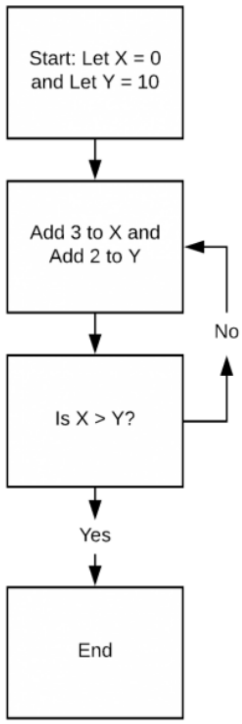
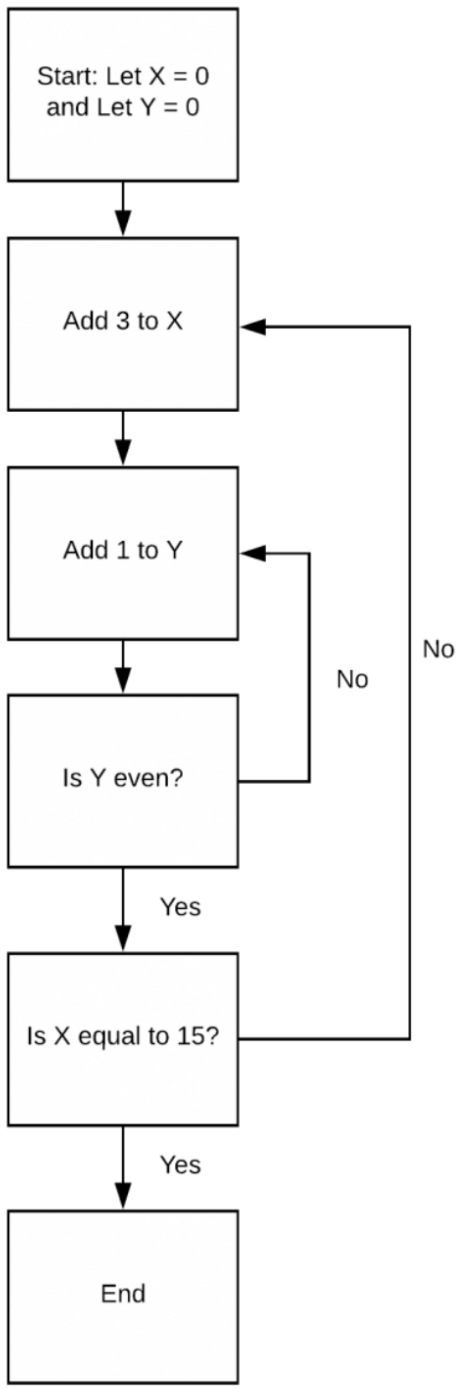


What is the value of X at the End of the flowchart?

What is the value of Y at the End of the flowchart?

Block 8

Below shows a logical flow chart. What is the value of Y by the End of the flowchart?


Start: Let X = 0
and Let Y = 0
Add 3 to X
Add 1 to Y
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