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THE ACADEMIC AND BEHAVIORAL IMPLICATIONS OF ROBOTICS IN THE CLASSROOM: AN ELEMENTARY CASE STUDY

Abbigail Foss, Caitlin Wilcoxen, and Joseph Rasmus

The Math and Science Academy, Williamston High School, Williamston, Michigan, MI, USA

There are many questions regarding the effectiveness of science, technology, engineering, and mathematics (STEM) education in increasing interest in STEM careers, creating possible behavioral effects, and impacting student achievement. Since STEM education is a broad category, this study focused on four impacts of teaching robotics to third graders. The aspects studied were classroom participation, behavior, math and engineering enjoyment, and math and engineering skills. Our hypothesis is that by learning technology (robotics), the students' math and/or engineering skills will increase and that they will show an improvement in their participation and behavior. Data was gathered on the four impact areas through behavioral observations, a survey, and a written skills level test. The written skills tests were given prior to the robotics lessons (pre-test) and after the lessons were done (post-test). Three sample groups were used in this study. T-tests were performed on each of the four impacts (participation, behavior, enjoyment, and skills) for the three different sample groups. With Group 1 (n = 44) and Group 2 (n = 22), our hypothesis of an increase in math and engineering skills was confirmed, as our p-values were both less than .05. Group 3 (n = 22) did show gains in engineering skills, but math results were inconclusive (1). Using a scale we designed, we then evaluated the behavior and participation of each student before, during, and after the robotics lessons. Each student was given a score from one to five in each category. From these results, t-tests were performed to determine significance. The data confirmed our hypothesis of improved behavior, as the p-value was less than .05. Thus, we can argue that teaching the students about robotics positively impacted the students both academically and behaviorally (2).

Key words: Technology; Innovation; Engineering education; Inventors

INTRODUCTIONS AND PREDICTIONS

The focus of this research is to determine if the learning of technology has an effect on the math and engineering skills of participating students as well as on their general interest in science, technology, engineering, and mathematics (STEM). The increased emphasis on STEM in the U.S. is due, in part, to the shortage of professionals with the necessary degrees in the fastest growing job fields. Researchers believe that beginning innovative STEM programs at an early age will increase overall interest among students. It is our hope that by showing the positive impacts of using technology, and specifically robotics, in the classroom, schools will look at this as a viable option for inspiring such increased interest moving forward.

This research will help determine factors that can improve students' overall academic performance as well as social interactions, thus leading to the next generation of inventors and innovators. Our research will help define the impact of the teaching of robotics

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Address correspondence to Abbigail Foss c/o Joseph Rasmus, Math and Science Academy, Williamston High School, 3939 Vanneter Road, Williamston, MI 48895, USA. Tel: +1 (517) 655-2142. E-mail: 19FossAb@gowcs.net, RasmusJ@gowcs.net

on the students' grades. This research could lead to students who typically struggle in math and science being able to make connections to STEM concepts that they could not make in a typical learning environment. The way students learn is not uniform, so this research could allow students who typically struggle to make connections not made in a traditional classroom. As previously mentioned, there is a shortage of professionals entering STEM-related fields. Through interaction with the robotics kits (the tools used to teach the robotics lessons), students may gain a greater interest in entering one of these fields. After all, a primary purpose of the STEM movement in the U.S. is to fill the positions in these growing fields.

In the past decade, technology usage has increased exponentially, and now technology is being integrated into education without the necessary understandings of its effects. Most parental worry focuses on daily life technology, such as cell phones or personal computers; however, this study is focused on robotics. Very few studies have been done on this topic, and those that have been done are on other types of technology, attempting to answer other questions, or using other variables. The independent variable of this study is the addition of the technology element to the students' education, with us teaching them. The dependent variables are the participating students' grades, interest, behavior, and participation.

STEM education offers an unmatched learning experience in the classroom that is vital to the development of not only future STEM career paths but also future inventors. Starting STEM education at a young age allows students to develop a passion for these subjects, which makes them more likely to go into those career paths, and increases the amount of hands-on education they receive, further fueling those passions and creating inventors. By letting young students create in the classroom, it makes students more likely to enter fields where they are allowed to use their imaginations and express themselves through invention. Hands-on education increases focus in the classroom and has a multitude of benefits that will be further discussed later in this paper.

Our hypothesis is that by learning technology (robotics), the students' math and/or engineering skills will increase and that they will show an improvement in their participation and behavior. This study was conducted within the confines of a suburban elementary school in the Midwest at the third-grade level. The results collected from a suburban elementary school in the Midwest do not necessarily reflect the results of a larger scale study.

REVIEW OF RELATED LITERATURE

Technology has revolutionized every aspect of our society, and education is no exception (2). Since the integration of technology, specifically computers, into classrooms in the late 1990s, many case studies and observations have been conducted in an attempt to verify the effectiveness and impact of technology on the development of young minds. Many parents are against the usage of technology in classrooms because they are unfamiliar with it and assume negative effects outweigh the positive outcomes (3). This literature review will explore many aspects surrounding the success of technology in the classroom and serve as an introduction to the subsequent case study.

Studying technology's impact in the classroom is made even more difficult by the fact that it is constantly changing (2). Since technology became commonplace in classrooms, so much has changed, as we have shifted from overhead projectors to smart boards and much more. Schools cannot keep up with the ever-changing technology, making it even harder to incorporate into the classroom. Through these changes, some positive impacts were identified, specifically the correlation between the improved focus of children with Attention Deficit Disorder (ADD) or Attention Deficit Hyperactivity Disorder (ADHD) and playing educational math games on a computer versus playing paper-based math games (4).

Another prominent theme we found was how each student learns differently, similar to how each piece of technology aids learning differently. Technology can help students learn in unique ways that a traditional class cannot provide (5). As mentioned by Brown, incorporating technology such as Chromebooks, SMART Boards, and the robotic kits that we used gives the opportunity to explore the learning styles of different students and tailor the students' education (6). In addition to individually tailored learning, hands-on technology has also been found to increase student collaboration and diversify thinking. Technology in the classroom increases student collaboration through group projects. Working in small groups, rather than as a whole class, has been shown to make students more comfortable and willing to participate and add valuable information to the discussion. This newfound collaboration improves students' socialization skills, which is beneficial to their futures. The social skills developed through group discussion can help them in the future and increase other valuable skills applicable in STEM professions. Technology can give the students social skills that they would not be able to develop in a traditional classroom setting. Coupling hands-on technology and small group work increases the initial benefits of working with technology in the classroom (7).

Through incorporating technology, such as robotics, not only are students willing to collaborate more, but they can also understand more difficult math topics, such as unit conversion with fractions (7). Technology can also provide a new and easier way for students to understand abstract concepts. There are many math games and activities that are reliant upon technology to keep students engaged while also improving comprehension skills, thus turning the classroom into a more productive environment for the teacher and the students. Teachers want the students to understand the concepts, but they also want to give them an enjoyable experience so that they will continue to want to learn (8).

In recent years, the number of STEM programs across the country has drastically increased due to the lack of educated professionals in many STEM career paths (9). This has had a direct impact on the usage of technology in classrooms around the world because not only is technology a useful amenity, but now it is almost a necessity in many of the fastest growing job fields. Due to a lack of known long-term integration effects and comprehensive reviews, many teachers and school districts are unaware of the tremendous benefits STEM programs can have on students' overall academic performance (10).

Teachers are the ones that make education possible, yet they often receive little support in the form of curriculum. Typically, teachers are just given requirements to meet with their teaching, and while this is good because it allows for lots of creativity, it does not ensure that teachers understand the materials they are teaching with, specifically technology. It is beneficial if the teachers know how to use the technology and troubleshoot to better assist the students (11). Workshops would help teachers understand exactly what technology they would use with the students and maximize the effectiveness of the technology on the students' academic experience. Teachers have also seen improvement in the classroom with things such as student collaboration and academic improvement (12). These changes can occur through simple things, such as watching a video before they go to class or writing to an electronic pen pal instead of a pencil and paper one. Using Microsoft Word and other programs can help students become technologically literate and help lead to these improvements (13).

A final aspect of our case study was measuring student participation. To track the improvement or decline of students behaviorally, we designed our own scale (Figure 2). The scale ranged from one to five. We then rated each student on behavior and participation (both small and large group). To help us get a clearer idea of their behavior and participation, we conducted observations at the beginning of the case study. This also helped identify the students who had difficulty in social interactions or students who might need extra focus from us when it came to compromises or decisions in their small groups (14).

METHODOLOGY

For this study, third graders from Walkerville Elementary School were taught how to build and program robots using LEGO® WeDo 2.0 robotics kits. This study measured interest levels in STEM, positive effects on their math and science grades, levels of increased participation, and behavior. To test these areas, we went to the school three days a week for 17 weeks. On the days we did not go to the classroom, we made lesson plans and analyzed data.

We administered a pre-test to all students in both (math and engineering) subject areas. Before we began teaching any lessons, we observed the participation and behavior of each child and rated them on scales we had designed (Figure 2). We began with initial observations to create a baseline for each student, allowing us to track how both aspects (behavior and participation) changed throughout the course of the study. We administered the post-test and did final participation and behavior evaluations after we finished the lessons with each group. We tracked behavior, participation, and interest levels during the study.

In week one, participation and behavior scales were fine-tuned, and the pre- and post-tests were designed. Week two consisted of initial observations made of the participants' behavior and participation. The observations were made using the scales we had created. We excluded one student from Group 1 (double classroom) from the data due to the fact that they are far below a third-grade learning level. We administered a pre-test in both math and engineering, which was the basis of academic growth/improvement for the study.

Weeks three through nine were spent teaching Group 1. The majority of the study consisted of us leading lessons with the participants. In these lessons, we taught the children how to build and program the robots. When working with the students, we created interactive lessons in order to keep them engaged and excited. Those lessons included matching the word to the robotic piece as well as fill in the blank with robotics words. The first lesson we did with each group was an interactive SMART Board activity. We created hand or body motions associated with each important part of the robot that we would be referring to often in the future. The activity of associating these motions with each vital piece they would be building with was designed to help the students remember the part as well as its function. The second part of the lesson was having each student label the parts on diagrams on the SMART Board as well as finish sentences about the function of each part. This helped us to figure out who was struggling and gauge how well the group was doing as a whole at understanding the material before we started the building process. After the initial lesson of an overview of parts, the students were given a choice between two LEGO projects to build. Each group was to decide democratically which project their group would complete. Of the ten groups, five chose to build "Milo" and five the "Dump truck." For this first project, they were to follow the LEGO instructions found on the LEGO website on the Chromebook that we set up for them. This was meant to allow them to familiarize themselves with the parts and how the robot's parts move and work. During the building times, we would walk around and help answer questions if they could not understand how the parts fit together. We also focused on making sure the groups were functioning as cohesive teams.

Following the building, they were introduced to programming. The software we used was the LEGO WeDo 2.0 App that came with the kits. To introduce them to programming, we once again created an interactive lesson. Rather than using JavaScript, the program's main functions were represented by blocks (Figure 10). Each block represented a different function of the robot: forward and backward motion, sound, and color. These blocks would then be dragged to the middle of the screen to create their programs. There were several programming elements clearly designed to make it more enjoyable and engaging for the students, such as the color and sound effects. After programming was explained and the students were able to attempt it and ask questions, the next project was revealed. Each group was required to use their creative skills and only the materials in their kit to build a car that drives as fast as possible. Before the groups started building, we gave a short lesson on gear ratios to help the students get their ideas moving and also to see how many groups were able to understand and successfully implement this more abstract and difficult concept. Although not all the groups included a gear ratio, we still received many questions from the students on how exactly the gear ratio worked as well as how to implement it on their race cars. At the close of the study, the groups were able to race each other in a bracket-style, single-elimination race—once again keeping the students engaged and giving them an end goal to encourage them to put their full effort into their cars.

The robotics activities used with Groups 2 and 3, over weeks thirteen through seventeen, were relatively similar to those used with Group 1. Group 1 was a double classroom (a group of 44 students who learned together during the entire school day), while Groups 2 and 3 were individual classes of 22 students. The small groups in which the students built their robots were all made up of students from the same class. However, several slight changes were made.

From the first group, we learned to streamline the teaching process and give extra help in the areas in which the prior group had struggled. We made sure the lessons were as straightforward and understandable to third graders as possible. We also spent extra time on programming and gear ratios to make sure that, even if the groups did not implement the concept, all students understood what a gear ratio does and why it is helpful. This extra time explaining and teaching about gear ratios led to more groups implementing the gear ratio into their robots and having a greater understanding of how their robots worked. With the extra overview in programming, we went more in depth about the functions of each block. Due to a time crunch, we only allowed the groups to do "Milo," as it took less time to build and the building process was more applicable to the second project. The second project stayed the same, once again with the researchers and the teachers only answering questions and allowing the cars to be the creations of the students. Throughout the research with both groups, we performed behavior and participation observations and ratings three times: at the beginning, after the first project, and a final evaluation after the second project.

After we finished our work with the students, we gave the post-test to the first group as soon as they could fit it into their schedules after we had finished the study. We also administered the interest level survey as soon as we finished our time with the students because we felt their answers would be more accurate at that point because they could more clearly remember their robotics experiences. Following the final week of working with the second group, we analyzed the data, created charts, and performed hypothesis testing to see if the students' academic performance and behavior had changed.

Of the third-grade population at Walkerville that we worked with, about 25% are economically disadvantaged and receive some type of aid from the school or local organizations within the community (either reduced/free lunch or food programs in the community). The racial demographics show that 89.2% of the third graders were Caucasian. Approximately 30% received some type of extra support outside of the classroom (either special education or reading support); however, we worked with all students, regardless of academic level. Of the third-grade population, approximately 60% were boys and 40% girls.

We repeated this process with a third class, Group 3. The process was the same as it was for Group 2 because we felt the way we taught Group 2 worked best. Once we finished with all the groups, we began analyzing the data.

RESULTS

The designed intervention with third-grade students showed an increase in positive participation, an increase in favorable behavior, and an equal or greater interest in math and/or science. Participation scores were measured by whole class and small group contributions, while behavior relied on disruption and how often the student was off task. Through hypothesis testing, we determined that our hypothesis is largely supported by the increases in math and engineering scores. We used a matched-pairs test because we focused on the same population and gave each group a pre- and post-test at different times. We also noticed that when students were asked how likely they were to go into a math and/or science career (at the end of the interest level survey), females said that they were more likely to enter those fields. This raised several questions among the researchers and the teachers, as STEM professions have a dearth of women entering those fields. So, what happens between now and adulthood that makes females less likely to enter those fields? Why are females currently more interested in math and science overall? Is this generation the "turning point" in evening out the gender gaps in STEM professions, or will they lose interest before college and entering the workforce?

DISCUSSION AND CONCLUSIONS

Our hypothesis stated that students' academic performance would improve, student interest in STEM would improve, and students' behavior and participation would improve by creating and programming robots. Due to the unusually high interest in both subjects, many of the students' interest levels started at an 8, 9, or 10 and increased typically up to a 10. Since this is not a normal distribution because the data was left skewed, we were not able to perform hypothesis testing on the interest level survey data but were able to tell that a majority of students did enjoy at least one of the subjects more than when we started. We analyzed the differences between the initial interest level survey before we began working with them to the change in score at the close of the study. We performed hypothesis testing on math, engineering, behavior, and participation, the results of which mostly supported our claims, as only the math test of a single class did not support the hypothesis. The p-values of the math tests were $p < .05$ for Groups 1 and 2 and, as stated earlier, $p > .05$ for Group 3. The third group's results were the only results whose hypothesis testing was not less than .05. Therefore, we cannot reject the null hypothesis. This means that in the case of the hypothesis testing of Group 3, we cannot conclude that our work with the students had an effect on their math scores. All three classes' hypothesis tests of engineering were supported with p-values of less than .05 for all three groups (1). The engineering pre-tests were mostly to help us see how much the students had learned and how well they were understanding the information we taught them. Among all three groups, students showed almost equal interest in both math and science curriculum after we had finished working with them.

The way we used the LEGO WeDo 2.0 was similar to how Leys explained and used technology in his study (4). Technology has become an even greater influence on our society since Leys' article was published in 2013, and there are many more possibilities for educational apps and games now. As mentioned earlier, there has been little comprehensive research done on STEM integration into classrooms that is similar to what we have done. We were able to fully realize the positive effects of the robotics on the students. Not only did they thoroughly enjoy it, but it had a truly beneficial impact on them and their learning and demonstrated real-world applications of STEM (7). While our results did support our hypothesis, it is only one case study, so we would recommend that there be more extensive research done specifically with these robotics kits as well as an investigation into other types of beneficial hands-on technology for either small or large groups. While we were working with the students, they were also learning fractions. Fractions are a more abstract concept that many students struggle with. All of our lessons were interactive, which helped the students stay more engaged, an argument further supported by Faisal (10). The small group environment

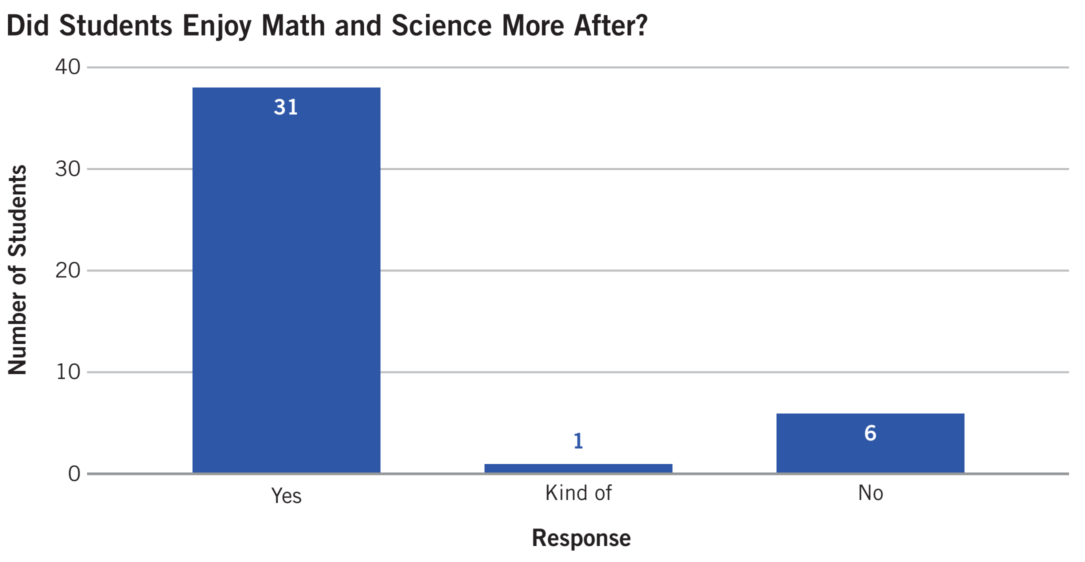

Figure 1. This chart was based on the interest level survey we gave out after the study. The survey asked if the students liked math and science more now that they have knowledge about robotics. 84.4% (38 of 44) of those students said yes, which showed that their interest did increase after this study.

1 (Worst)	2	3	4	5 (Best)
Behavior				
• Not focused at all • Distracting others • Excessive talking during the lesson (if not constantly) • Blurting out • Zoning out 12 or more times	• Minimal focus • Zoning out 9 to 11 times • Occasionally distracts others or is easily distracted • Blurts out 3 to 5 times • Spends over 50% of the lesson talking	• Focused about half of the time • Zoning out 5 to 9 times during the lesson • Intermittenly distracted and slightly distracting to others	• Focused a majority of the time • Zoning out 3 to 5 times during the lesson • Minimally distracted • Rarely distracts others	• Adds relevant and beneficial points • Keeps other group members on task • Asks questions when needed
Participation				
Small Group • Not working with the group; either working alone or on something else • Distracts other group members • If participates, adds unhelpful or unimportant information **Large Group** • Blurts answers or adds irrelevant information • Does not participate at all	**Small Group** • Minimal work/ effort put into the group • Majority of time is spent distracting others/self • Adds few helpful ideas **Large Group** • Blurts often • Minimally participates • Few relevant points	**Small Group** • Participates with the group half the time • Distracts others/ is moderately distracted • Adds some helpful ideas and relevant information **Large Group** • Blurts occasionally • Participates half the time • More relevant points than not	**Small Group** • Participates 75% to 85% of the time • Adds helpful and relevant informa-tion most of the time • Rarely distracts group members **Large Group** • Blurts minimally • Participates a majority of the time • Usually adds relevant and helpful information	**Small Group** • Adds relevant and beneficial points • Keeps other group members on task • Asks questions when needed **Large Group** • Adds relevant and beneficial points • Asks questions to clarify and responds to questions

Figure 2. This is the chart used to measure behavior and participation. We went through and gave certain criteria for different levels of behavior and participation. Participation scores were not only based on large group settings but also on small group work. We also did a matched pairs t-test for this, as we tested the same group of students and collected the data from two separate points in time. As we performed hypothesis testing, both participation and behavior for all three groups confirmed our hypothesis, as the p-value (1) was less than .05 for all groups on all behavior and participation tests (15).

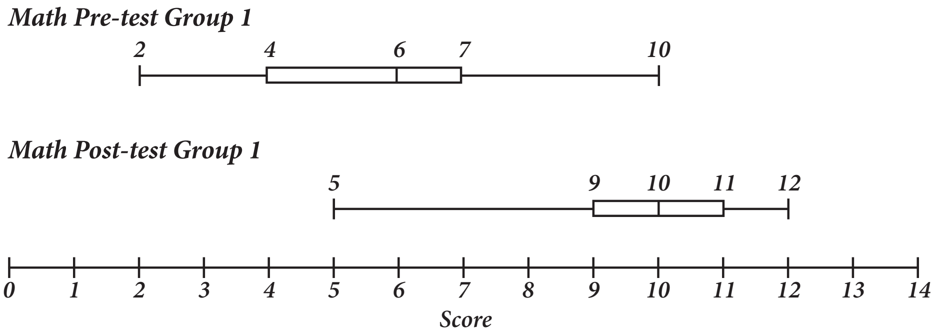

Figure 3. After we had all of the tests completed, we made five-number summaries of the pre-tests and post-tests. The boxplot on the top is the pre-test, and the one on the bottom is for the post-test. These boxplots are specifically for Group 1. As shown, the scores for math increased significantly, indicating that our methods could have helped them.

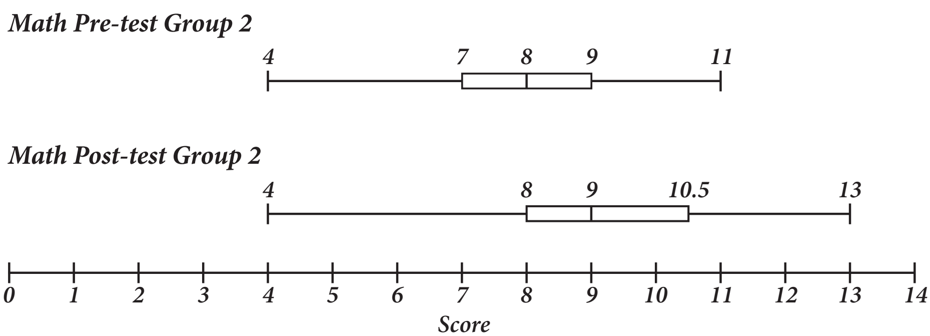

Figure 4. These are the math boxplots for Group 2. Although their scores did not have as big of a shift, there still was a slight improvement in their scores.

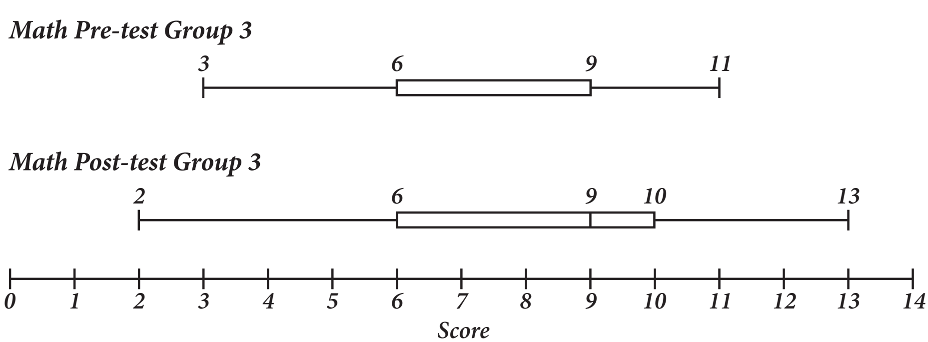

Figure 5. These are the last boxplots we have for the math pre-tests and post-tests. Group 3 was a trouble spot in the sense that some kids improved, but some did worse. Thus, we cannot reject the null hypothesis of improvement of math scores specifically.

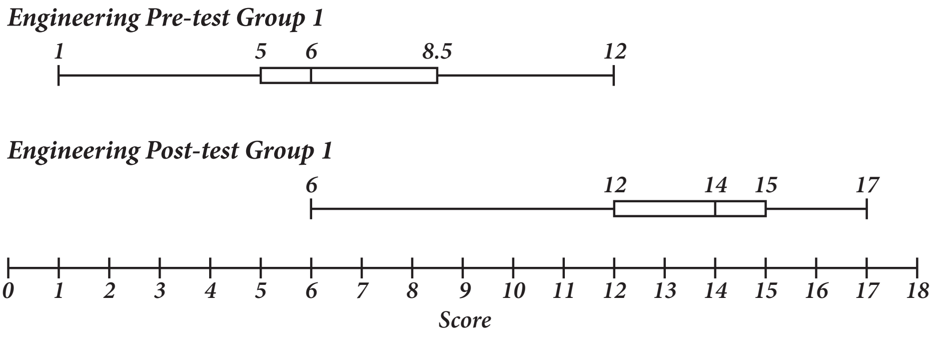

Figure 6. We also calculated the five-number summaries of the engineering pre-tests and post-tests. These tests were originally our way to test the growth of their science scores, but they ended up having more engineering questions than science questions.

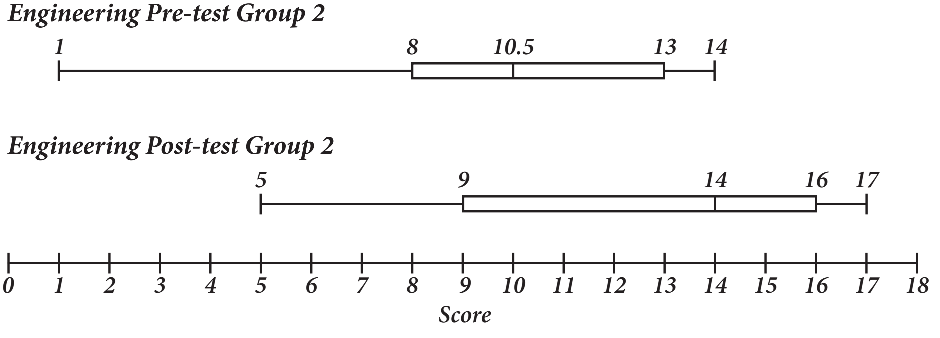

Figure 7. These are the engineering boxplot scores for Group 2. They improved significantly, showing that they gained knowledge about robotics.

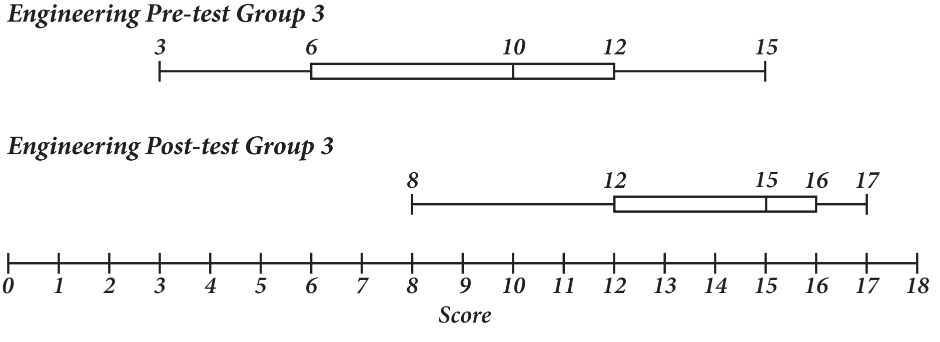

Figure 8. These are the final boxplots for engineering from Group 3. They improved in the engineering section. There is clear evidence that they learned engineering concepts from us.

	Math P-Values	Engineering P-Values
Group 1	5.84*10^-20	2.172*10^-19
Group 2	.03	5.542*10^-5
Group 3	.053	3.727*10^-8

Figure 9. A visual representation of the hypothesis testing scores from all three classes. As mentioned earlier, the hypothesis testing scores for the engineering tests of all groups far exceeded the p-value needed to confirm the hypothesis. The hypothesis tests also helped to confirm our hypothesis that, through learning robotics, the students' math scores increased. Only in Group 3 could we not reject the null hypothesis (1).

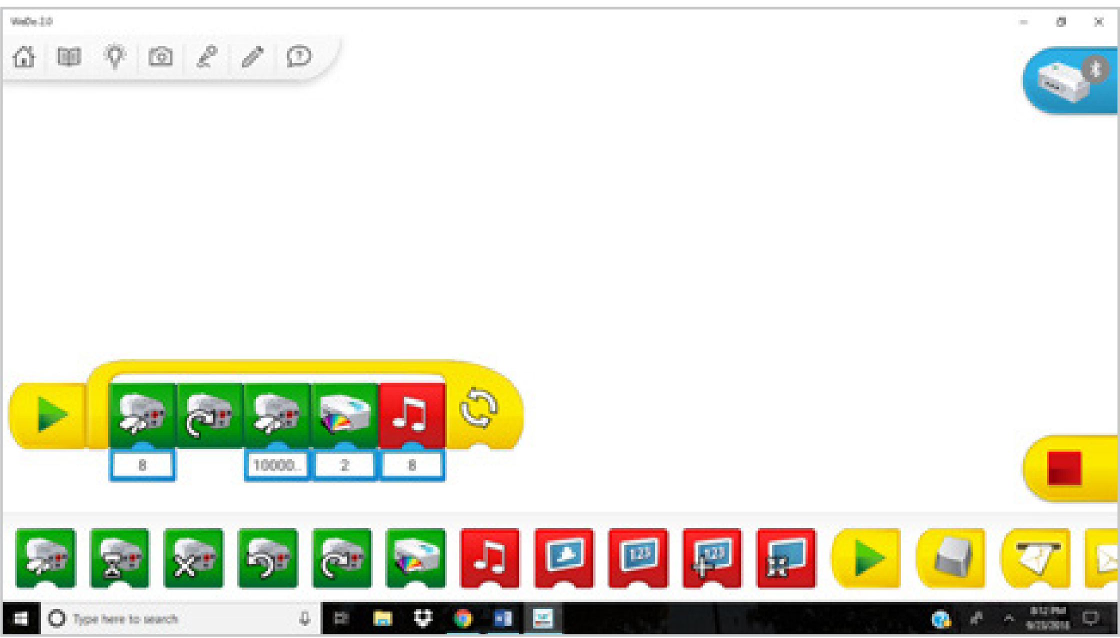

Figure 10. Here is what the programming looked like in the LEGO WeDo app. The functions are blocks, and each block represents a different function. For example, the first green block in the bottom left of the screen is the block that makes the LEGO creation move.

forced students to work together to finish their projects and increased the class' participation not only in those small groups but in whole class discussions as well (10). Our paper had similar results to "How Technology Can Encourage Student Collaboration," a study about technology's role in fostering a positive work environment.

This study helps to define the broad spectrum that is invention education. It has helped pinpoint specific benefits and effects of using robotics in the classroom. While here this was limited specifically to this type of robotics, it could be generalized once more research is done. It has helped to further our understanding of robotics and hands-on education in the process of creating inventors as well as the impacts on academics. Further research could be done to see the benefits of invention education beyond this study. While this study provides a basis for those studying invention education, a long-term study would be best to continue and find the life-long effects of not only invention education but also to learn how involved students are with invention in the future.

Despite our positive results, there are some things that could be done to improve our process. The research could be continued with additional third-grade students, younger students, or possibly another school district. This study was performed on a large number of students relative to the size of the Walkerville School District, but it is a relatively small sample to represent demographics outside those represented in the school district. For more conclusive results, this study could be done with a larger sample and be done outside the Walkerville population. The behavior and participation scores were based on a scale of our creation, and the scores given to the students could contain bias because we worked with them so closely. The students also rated their own interests, making it hard to know how accurate those ratings are because the participants are very young. Our research also raised many important questions, including the following: If female students are more interested in STEM currently, what happens to make them change their career pathway and/or lose that interest in STEM subjects? This is something that should be researched further to explore more options.

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