The Effects of Using Finch Robots to Teach Math on Middle School Students' Math Self-Efficacy and Achievement

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Author Note

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Conflict of Interest

The author has no affiliations that may be perceived as conflicts of interest on the study.

Abstract

Science, technology, engineering, and mathematics (STEM) education is significant for a vibrant national development and economy. Successful math education at middle school level is one of the important factors which contribute to student's success in STEM education in high school and college. However, most students perform poorly in mathematics at middle school. Use of educational robotics in mathematics education seems to have potential of improving students' math achievement and self-efficacy. In this study, I used mixed method design to investigate the effects of using Finch robots to teach math on middle school students' math self-efficacy and achievement. I used mathematics self-efficacy survey and mathematics achievement test to collect qualitative data. And I used observation to collect qualitative data. To analyze quantitative data, I used General Linear Model (GLM) within the Statistical Package for Social Science (SPSS) version 28 computer program. Analysis of the quantitative data suggested that use of Finch robots have a significant negative within-subjects effect *(F* (1, 4) = 35.41, *p* = .009) on students' math self-efficacy. However, analysis of qualitative data revealed a positive effect. Regarding students' math achievement, analysis of quantitative data revealed nonsignificant within-subjects effect, *F* (1, 4) = .314, *p* = .614. Contrary, analysis of qualitative data revealed a positive effect.

Keywords: educational robotics, mathematics education, math self-efficacy, math achievement.

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Importance of STEM

Science, technology, engineering, and mathematics (STEM) education is considered as a vital tool for understanding and solving problems in the constantly changing world (Changtong et al., 2020; Coxon et al., 2018). Teaching STEM subjects is of significant importance for economic development of the nation and the world at large (Changtong et al., 2020; Coxon et al., 2018). Successful mathematics achievement in middle school is a gateway to STEM courses such as computer science and engineering. Unfortunately, due to stereotypes and poor early math and science education, many students perform poorly in mathematics and tend to consider themselves that they are not good at math and science before or when they are in middle school (Coxon et al., 2018).

Educational Robotics (ER)

Integrating educational robotics (ER) in teaching and learning can help to improve students' achievement in mathematics because it seems to be a potential tool for engaging and motivating all students regardless of ethnicity, gender or socio-economic status (Barak & Assal, 2018; Muñoz et al., 2020). ER is the study of designing, constructing and using robots with the purpose of helping students to learn effectively (Muñoz et al., 2020). There is an increasing use of ER because robots seem to spark the imagination of students because they seem to replace human beings in doing various tasks (Barak & Assal, 2018). Moreover, ER can be instrumental for improving learning and achievement because it provides opportunities to engage and motivate students in learning by doing (Muñoz et al., 2020; Coxon et al., 2018; Barak & Assal, 2018).

Use of ER for teaching and learning can involves programming or coding robots in such a way that they facilitate achievement of stated learning objectives (Muñoz et al., 2020). Programming or coding a robot simply means writing instructions or commands which will be implemented by the robot (Muñoz et al., 2020; Coxon et al., 2018). Programming or coding robots can help students to develop and improve problem-solving and logical-mathematical skills, as well as analytical and creative thinking skills (Muñoz et al., 2020; Coxon et al., 2018). Robotics (coding or programming robots) is fundamental not only for mathematics but also other STEM disciplines and is critical in helping learners to acquire the twenty-first century competencies (4Cs) namely Critical Thinking, Communication, Collaboration, and Creativity (Miller, 2019).

Previous Studies on Educational Robotics (ER)

Many studies have been done on the effects of using robotics in teaching mathematics in elementary, middle, and high schools. But there is no consensus in these studies about the effects of use of robotics in mathematics education on students' mathematics achievement, and interest (Zhong & Xia, 2020). Some researchers found that use of robotics in teaching of mathematics have positive effect on students' mathematics achievement (Alfieri et al. 2015; Palmér, 2017; González‑Calero et al., 2019; Muñoz et al., 2020), and students' interest on mathematics (Ching et al., 2019; Palmér, 2017). However, some researchers found that use of robotics in teaching of mathematics has negative or no effect on students' mathematics achievement (Lindh & Holgersson, 2007; Walker et al., 2016), and students' interest on mathematics (Alfieri et al., 2015; Conrad et al., 2018; Dohn, 2020). Because there is no agreement among scholars about the effects of using robotics in mathematics education, more studies need to be conducted to explore more about the potential of using robotics in mathematics education (Zhong & Xia, 2020)..

In my search of the previous studies on the use of educational robotics in STEM, I could not come across any study which specifically investigated how the use of educational robotics affects students' self-efficacy. However, findings in other studies which did not involve use of educational robotics show that, students' self-efficacy has a positive significant relationship with students' achievement (Bresó et al., 2011; Britner & Pajares, 2006a; Kaya & Bozdağ, 2016).

In the studies cited above, different types of robots were used, such as LEGO Mindstorms (Conrad et al., 2018; Ching et al., 2019;), Bee-Bot (Palmér, 2017; Muñoz et al., 2020), Expedition Atlantis Robot (Alfieri et al., 2015**),** Ozobot (González‑Calero et al., 2019**),** and Scratch (Dohn, 2020). New educational robots are being developed and made available for use every year. Studies of how the use of these new robots can affect teaching and learning of mathematics are needed. Therefore, in my study I used Finch Robot 2 to teach geometry to middle school students in order to explore more about the effects of robotics in mathematics education. I provided more details about Finch Robot 2 in the material sub-section under methods section.

The Purpose of the Study, Research Questions and Hypotheses

The purpose of this study was to investigate whether the use of Finch Robot 2.0 for teaching mathematics to middle school students helps to improve both their mathematics self-efficacy and achievement. The major question which the study wanted to answer was, what are the effects of using Finch Robot 2.0 in mathematics education on students' mathematics self-efficacy and achievement? In particular, the study sought to answer following questions (1) How the use of Finch Robot 2.0 in teaching geometry to middle school students affects their mathematics self-efficacy? (2) How the use of Finch Robot 2.0 in teaching geometry to middle school students affects their mathematics achievement? (3) What is the relationship between student's mathematics self-efficacy and their achievement in mathematics? I proposed three alternative hypotheses for the study: (i) after participating in the study program, students' self-efficacy in mathematics will increase, (ii) after participating in the study program, students' achievement in mathematics will increase, and (iii) there will be a significant positive relationship between students' mathematics self-efficacy and their mathematics achievement.

Methods

Setting of the Study

I conducted this study in a charter school in Pittsburgh area. The school is designed to serve children with Dyslexia. Most of the students at the school come from low socio-economic communities, 100% of the students are eligible to receive free or discounted lunch. For three years the school runs a free summer camp program for its students in the months of June and July. The summer camp is supervised by director of after school program. All students at the school are invited to participate in the summer camp program. Parents are required to register their children if they want them to participate in the summer camp. In the summer camp program, I served as a middle school teacher. I conducted this study during the 2021 summer camp program which lasted for six weeks. In each week, the summer camp was held Monday thru Thursday, from 8:00am to 1:00pm. The school provided free breakfast and lunch for students who needed them. Also, the school provided transport for students who needed.

Study Participants

The participants of the study were six middle school students. Two of them were girls, and four of them were boys. Five of them were rising sixth graders, and one was rising seventh grader. Regarding race, five of them were white, and one was Latin American. In this study report, I refer to individual participants by these names Student1, Student2, Student3, Student4, Student5, and Student6. Through the school's director of after school program, my research information flyer was sent as an email attachment to all parents who registered their children for the summer camp. Along with the research flyer, a Google form link of parent permission form was also sent to the parents. So, these students were registered by their parents to participate in the summer camp at the school. Each parent who wanted their child to participate in the study, electronically completed and signed a consent form to give permission for their child to participate in the study. Once a child's parent had signed the permission form, the child also electronically completed and signed an accent form to indicate their willingness to participate in the study.

Study Materials

Finch Robot

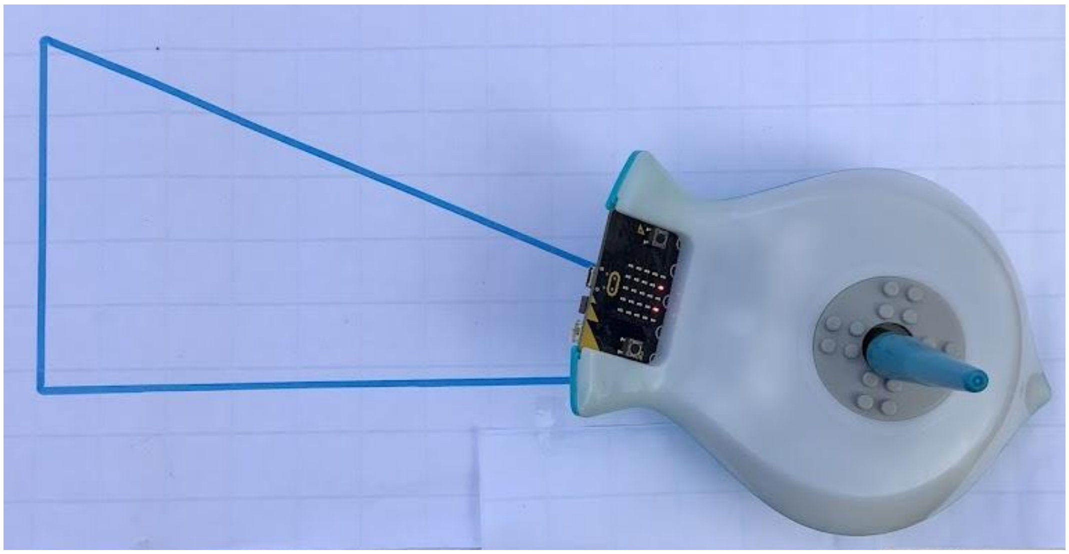
Finch robot 2.0 is a new programmable/codable robot, which looks like a bird (see figure 1), which was created by Birdbrain Technologies company. There is one unique feature which sets Finch Robot 2.0 apart from other robots. It has a special hole where you insert a marker pen to enable it to draw lines, shapes, or letters as programed/coded (see figure 2). This makes it very suitable for teaching and learning geometry. Finch robot 2.0 can be programed/coded in many programming/coding languages – FinchBlox, BirdBlox, Snap, MakeCode/JavaScript, Python, Java, Swift, and Kotlin. In my study, students used MakeCode to program the robots, MakeCode is a web-based app. I chose to use MakeCode because this is the software recommended to be used with Chrome Books by Birdbrain Technology, the maker of the robot. My students were using school provided Chrome Books to write codes for the Finch robot. I gave each student a Finch robot with a unique number on it, which they used throughout the study.

Figure 1

Finch Robot 2.0.

Figure 2

Finch robot 2.0 Drawing a Triangle



Other Materials

Other materials I used in the study were Post-it Super Sticky Easel Pads, 25 in x 30 in, and Washable Crayola Paint Brush Pens (see figure 3). After the students have coded their Finch robots, they put them on these pads so that they can move and draw triangles. Also, I used during the project were Washable Crayola Paint Brush Pens. These are special paint brushes recommended by the maker of the Finch robot. The brushes fit perfectly in a vertical hole on the Finch robot, that way it enabled the robot to draw lines as it was moving.

Figure 3

Other Materials I Used in the Study

Research Design

In this study, I used concurrent mixed methods research design. In concurrent mixed methods research design, both quantitative and qualitative data are collected and analyzed during approximately similar time period (Creswell & Plano Clark, 2007). Then, quantitative and qualitative results compared to better understand a research problem. Mixed methods research “can help to develop rich insights of a phenomena of interest that cannot be fully understood using only a quantitative or a qualitative method” (Venkatesh et al., 2013, p. 21). Greene (2007) and Venkatesh et al., (2013) recommend the use of mixed methods to collect and analyze data in order to enhance the degree of reliability and validity of the study. Many previous studies on use of robotics for teaching mathematics such as (Barak & Assal, 2018; Coxon et al., 2018;

Dohn, 2020; Ortiz, 2015) used mixed methods design. So, mixed methods design seems to be a suitable research design for conducting research about using robotics for teaching and learning. I used a 5E instruction model to implement different lessons during the study.

Data Collection

I used surveys to collect quantitative data about the independent variables of the study – namely students' mathematics self-efficacy and achievement. The students completed the same surveys before they started to use Finch robots to learn geometry, and at the end of the study. I used observation to gather qualitative data on the implementation of the learning activities (learning to draw different types of triangles through coding Finch robot). Important parts of the learning activities were video recorded for later review. Also, I collected hard copies of paper pads on which triangles were drawn.

Mathematics Self-efficacy Survey. In order to collect data on students' mathematics self-efficacy, I adapted questions from Usher et al. (2019) mathematics self-efficacy survey, and form Britner and Pajares (2006) science self-efficacy survey. My mathematics self-efficacy survey consisted of ten questions. Following are three sample questions: (i) In general, how confident are you in your abilities in math? (ii) How confident are you that you can get "A" or "B" grade in a geometry test? (iii) How confident are you that you will get the right name of this triangle? Students were supposed to indicate their confidence on five levels by choose one answer from the following options: not confident at all (level 1, the lowest level = 1 point), somehow not confident (level 2 = 2 points), somehow confident (level 3 = 3 points), or completely confident (level 4, the highest level = 4 points). I administered the same mathematics self-efficacy survey online through Google Form before students beginning to use Finch robot, and at the end of the project.

Mathematics Achievement Test. I developed a mathematics achievement test for my project. In particular, the test comprised ten questions about different types of triangles. Each question carried 10%, making a total of 100% for the 10 questions. The first five questions consisted of questions which wanted students to choose a correct name for a triangle displayed on an image. Each of the last five questions consisted of one characteristic of a triangle. From the four answer options given, students were supposed to choose the correct name of a triangle represented by the characteristic. For each question, students were supposed to choose a correct answer from four options given. The four answer options for each question were names of different triangles, namely right triangle, acute triangle, obtuse triangle, equiangular triangle, equilateral triangle, scalene triangle, and isosceles triangle. These are sample questions: (1) What is the name of this triangle? (An image of a triangle was displayed under the question), (2) A triangle where one of its interior angles is 90 degrees, (3) A triangle which has all three of its sides equal in length.

Observation. I observed my students as they were participating in the learning activities I gave them. A learning activity on each session required students to code their Finch robots to move in such a way that they can draw a specified type of triangle. I took notes of how they interacted with their robots, and with each other. In additional to taking notes, I adapted and used an observation rubric (Muñoz et al., 2020) to guide my observation of the learning activities. The observation rubric had descriptions of four levels of achievement at which students' performance on the learning activity could be placed (see table 1). For the purpose of future review, I asked one of my fellow teachers to video record parts of the learning activities which I thought were critical for the study. For example, when a student successfully coded their Finch robot to move in such a way that it draws a specified type of triangle. Moreover, I took some pictures of the triangles drown by the robots.

Table 1

Observation Rubric for Achievement of Learning Activities

Level	Achievement Descriptions
4	Student understands and completes the learning activity without the teacher's help
3	Student understands and completes the learning activity with minimal teacher's help
2	Student understands and completes the learning activity with lot of teacher's helps
1	Student understands the learning activity, but didn't complete it

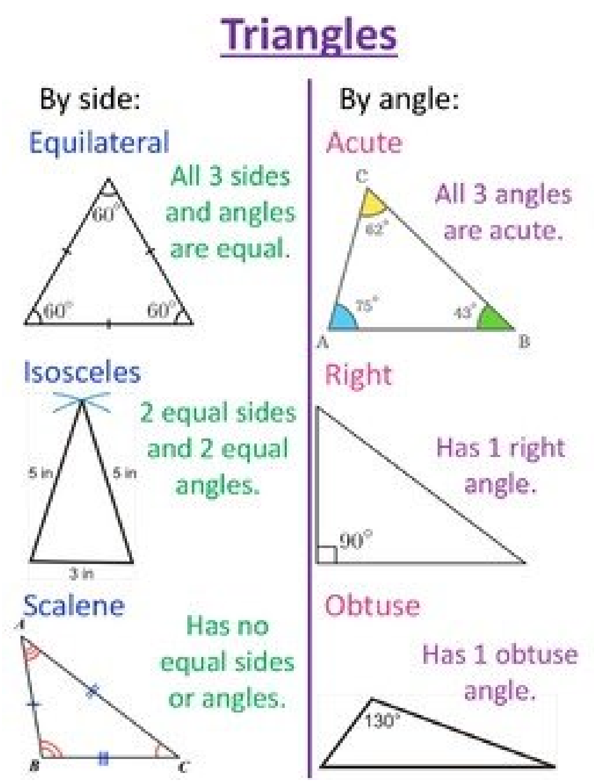
5E Instructional Model

In using the Finch robot to teach mathematics, I followed 5E Instructional Model in developing my lesson plan (see appendix 1). The 5E Instructional Model has five phases namely **E**ngagement, **E**xploration, **E**xplanation, **E**laboration, and **E**valuation (5E) (Bybee et al., 2006). The five phases of the 5E Instructional Model are designed to facilitate the process of conceptual change. Employing the 5E model in teaching brings coherence to various teaching tactics, and provides connections among learning activities, and helps teachers make logical decisions (Bybee et al., 2006).

The purpose of the engagement phase is to access the learners' prior knowledge and to trigger curiosity for learning new content. To access students' prior knowledge, I showed the students pictures of different types of triangles (see figure 4) and asked students to name them, and to list the characteristics of each type. Then, to trigger curiosity for learning new content, I showed the students a Finch Robot and told them that it can be coded to move and turn in such a way that it can draw different types of triangles. This made the students more curious to know how that can be done.

Figure 4

Different Types of Triangles



The exploration phase, aim at providing students with a common ground of activities. During this phase, I played a video showing a Finch Robot drawing an equilateral triangle. Then, I showed the students how they can use MakeCode website to code their Finch Robots to move forward, backward, and turns right or left at different angles. Then, I asked the students to do the same.

Explanation phase is intended to focus students' attention on implementing a particular aspect or concept of the engagement and exploration phases, and then to explain their understanding of the concept. So, I asked each student to use MakeCode web-based computer app to code their Finch robots to move and turn in such a way that it can draw equilateral triangle on paper pads. MakeCode web-based computer app uses block-based programing language for coding. Then, before running the codes, I asked students to explain how they coded their robots to draw equilateral triangles.

At elaboration phase, I challenged and extended students' conceptual understanding and skills by asking them to code their robots to draw other equilateral triangles with different sides' lengths. Finally, at evaluation phase, I students assessed equilateral triangles that were drawn by their Finch robot.

Data Analysis

I used Statistical Package for Social Science (SPSS) version 28 computer program to analyze quantitative data about students' mathematics self-efficacy and achievement. Within the SPSS, I used General Linear Model (GLM) Repeated Measures analysis of variance (ANOVA). The analysis produced descriptive statistics of the research independent variables of the study – mean score, standard deviation etc. The independent variables of the study were students' mathematics self-efficacy and achievement. The analysis also produced inferential statistics of the variables – significance p values and F values of tests of within-subjects effects and contrasts. I conducted the analysis based on $p < .05$ level of significance.

For qualitative data which I collected through observation of learning activities, I repeatedly read my observation rubric (see table 1) and notes. Also, I repeatedly watched video recorded learning activities, and viewed photos of learning activities. Then, I compared them with the hard copies of paper pads on which the Finch robots draw various triangles.

To achieve mixed methods design, I compared quantitative result with qualitative results. Table 2 shows how I compared quantitative results with qualitative results.

Table 2

Comparison of Learning Activities Achievement Levels with Students' Math Self-efficacy

Self-efficacy		Learning Activities Achievement	
Description	Levels	Descriptions	Level
Completely confident	4	Student understands and completes the learning activity without the teacher's help	4
Somehow confident	3	Student understands and completes the learning activity with minimal teacher's help	3
somehow not confident	2	Student understands and completes the learning activity with lot of teacher's helps	2
not confident at all	1	Student understands the learning activity, but didn't complete it	1

Findings

Quantitative Results

Students completed the Math Self-efficacy survey and the Math Achievement test on the first day of the study, before they started to use Finch robot to learn geometry. They also completed the same survey and test on the last day of the study. Six students completed the Math

Self-efficacy survey and the Math Achievement test at the beginning of the study. But four students completed the survey and test at the end of the study. Data of the two students who missed the last survey and test were excluded from the data analysis. In following subsections, I present the results of quantitative data analysis which I conducted in SPSS version 28. I conducted the analysis based on $p < .05$ level of significance.

Math Self-efficacy Survey

Table 3 presents the descriptive statistics of students' math self-efficacy in the pre-test and post-test survey. Scores are based on a four points scale – not confident at all (level 1, the lowest level = 1 point), somehow not confident (level 2 = 2 points), somehow confident (level 3 = 3 points), and completely confident (level 4, the highest level = 4 points). Table 4 presents repeated measures ANOVA results of the study variables. The results of students' math self-efficacy *Tests of Within-Subjects Effects* were F (1, 4) = 35.41, p = .009. The results of interaction between students' math achievement and self-efficacy were F (1, 4) = .286, p = .63.

Table 3

Students' Math Self-Efficacy Descriptive Statistics

Math Self-Efficacy Survey	Mean	Std. Deviation	N
Pre-test Math Self-Efficacy	3.167	.0680	4
Post-test Math Self-Efficacy	2.938	.5109	4

Table 4

Tests of Within-Subjects Effects

Source	df	F	Sig.

Self-Efficacy	Greenhouse-Geisser	1	35.405	.009
Math Achievement	Greenhouse-Geisser	1	.314	.614
Self-Efficacy * Math Achievement	Greenhouse-Geisser	1	.286	.630

Math Achievement Survey

Table 5 presents descriptive statistics of the two math achievement tests. Students took the first math achievement test at the beginning of the study and the second one at the end of the study. There was an interval of approximately four weeks between the first math achievement test and the second one. Results of *Tests of Within-Subjects Effects* are presented in table 4, F (1, 4) = .314, p = .614.

Table 5

Students' Math Achievement Descriptive Statistics

Math Achievement Test	Mean Score	Std. Deviation	N
Pre-test Math Achievement	52.50	28.723	4
Post-test Math Achievement	42.50	17.078	4

Qualitative Findings

In every session, I collected qualitative data through observation. I taught and observed my students as they were participating in learning activities. My lesson plan was based on the 5E Instructional Model. The 5E Instructional Model has five phases namely **E**ngagement, **E**xploration, **E**xplanation, **E**laboration, and **E**valuation (5E) (Bybee et al., 2006). For all four sessions, I followed all these phases, but I changed the contents based on a specific triangle which was a focus of the day. On the first session, there were only two students – Student1 and student5. The other students were absent from the school due to different reasons.

For the first session, during engagement phase of the 5E model, asked the students to mention names of different types of triangles. They were able to mention only two types – right triangle and acute triangle. On the classroom TV screen, I showed them an image (see figure 4) with six types of triangles (Teachers Pay Teachers, 2021). Then, I told the students that the Finch robot can be coded to move and turn in such a way that it can draw different types of triangles. Student1 eagerly said, "how can you do that?" I told them that I'm going to teach them how to do it. So, the students were so eager and excited to learn how they can write codes for the Finch robot. From the second session and other sessions after

At exploration phase, I played a short video which showed a Finch robot drawing an equiangular triangle as it was moving and turning. They were amazed to see that, and they were curious to learn how they can code the robot. Then, I started to show them how they can use MakeCode web-based computer app to write codes for the robot. Before giving the students the first challenge of coding the Finch robot to draw a triangle, I gave them opportunities to explore and try different codes. So, each one of them experimented different codes with their Finch robot. They coded their Finch robots to move forward, or backward a certain distance, turn right, or left at certain angle etc. When Student5 through my guidance, was able to code his Finch robot to move forward, then turn 180 degrees, Student1 amazingly said, "It can turn? It can turn?" Then, he asked me to show him how he can also code his Finch to turn around; and I showed him how to do it. He was so excited to see his Finch robot moving forward, then turning 180 degrees, start moving again.

During explanation phase, I challenged the students to use MakeCode computer app to code their Finch robots to move and turn in such a way that it can draw equiangular triangle on paper pads. An equiangular triangle is a triangle whose three interior angles are equal in measure (Math Open Reference, 2011). The three sides of an equiangular triangle are equal in length, for this case, an equiangular triangle is the same as equilateral tringle (Math Open Reference, 2011). To help them clearly understand the challenge, I displayed an image of an equiangular triangle on the classroom TV screen. On hearing and seeing the challenge, everyone started to figure out how they can they do it. After few unsuccessful trials, Student5 said “How do you do that?”, Student5 said “This is hard”. Then, I gave them some hints – your codes should include three “Finch Move” blocks, and two “Finch Turn” blocks. Also, I told them that, they may need to do several trials before they got it right. So, the student continued rewriting and rerunning codes for their Finch robot (see figure 5). I was giving them more hints after each of the unsuccessful trials. After, one of the unsuccessful trials, Student5 said, “I almost did it. I'm not giving up until I do it”. Finally, after several trials, the students were able to code their Finch robots to move and turn in such a way that they drew equiangular triangles (see figure 6). Figure 7 shows screen shot sample codes for an equiangular triangle. They were all happy for solving the challenge. Student1 shouted “Yeah, I did it.” Then, after successfully coding their Finch robot, I asked the students to explain how they coded their robots to draw the equiangular triangles. They were all able to explain their codes.

On different sessions, during elaboration phase, I challenged and extended students’ conceptual understanding and skills by asking them to code their Finch robots to draw the same triangle which was the focus of the day, but with different sides’ length or degree measures. Or asking them to draw the same triangle but which pointed on opposite direction from the one they have drawn. For example, during the second session when Student1 said, “I finished this challenge; can you give me another challenge?". And I said "Sure. Draw the right triangle pointing to the opposite side, left side". The student started to edit his codes to meet my instruction.

Figure 5

Several Trial and Error of Drawing a Triangle

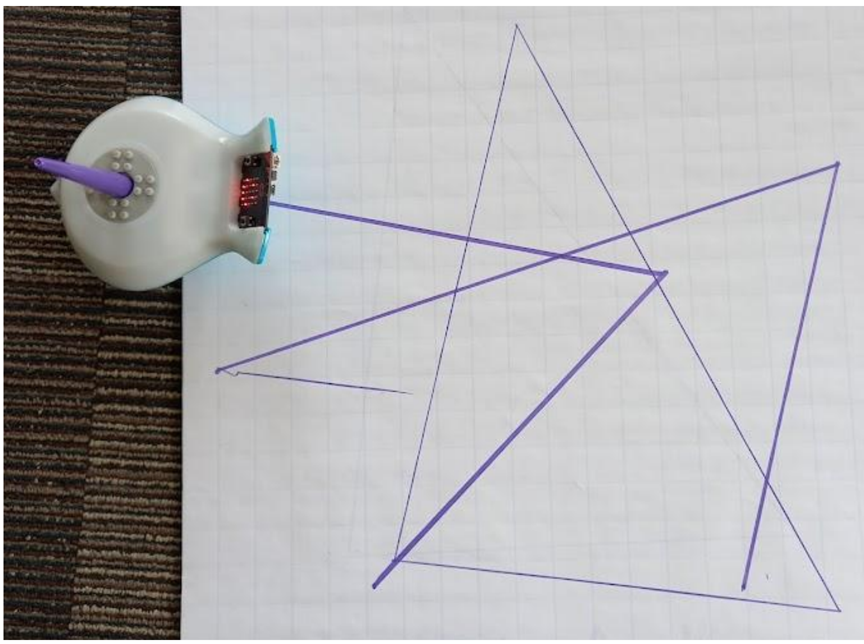


Figure 6

A Sample of successfully Drawn Triangles

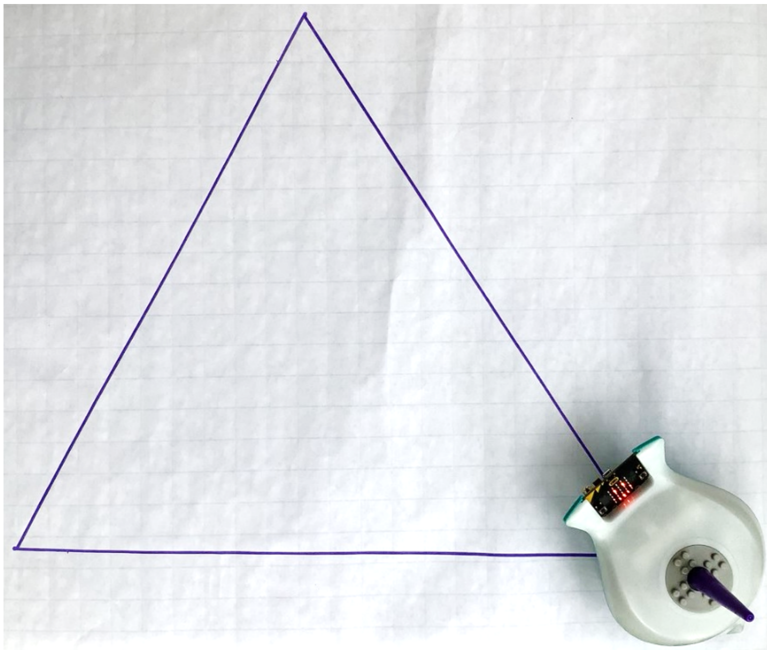
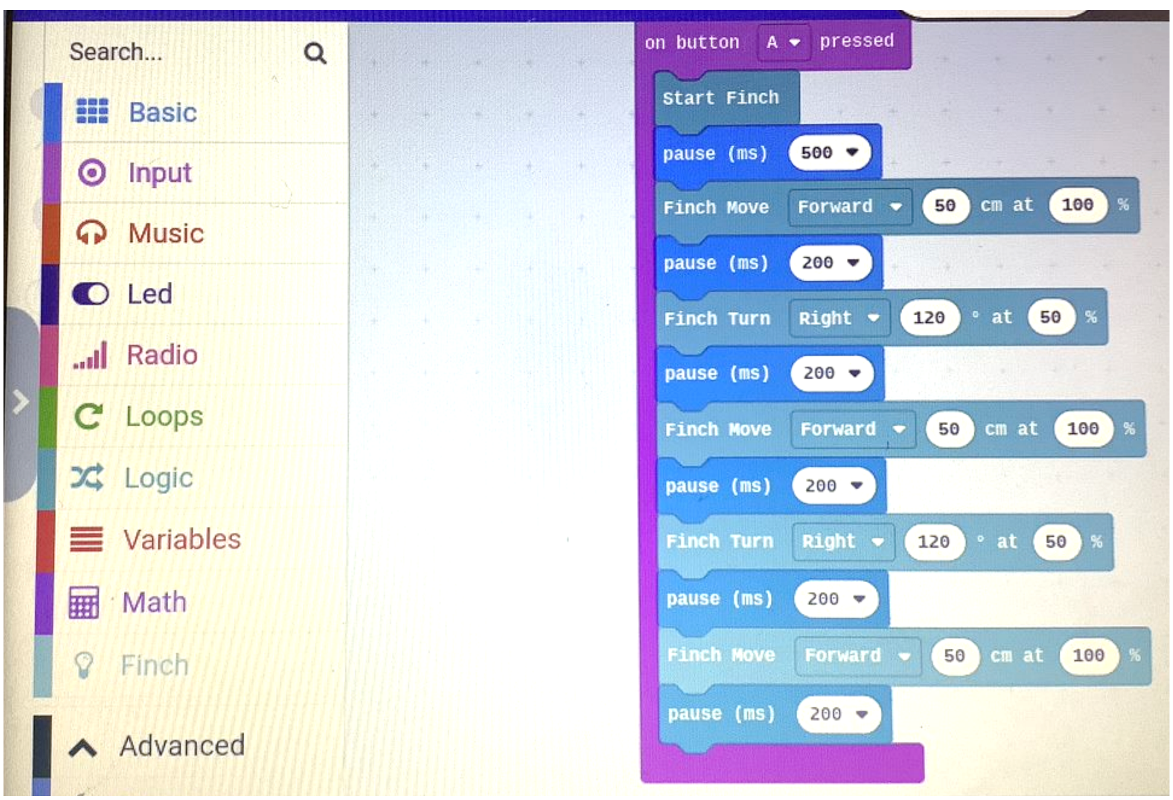


Figure 7

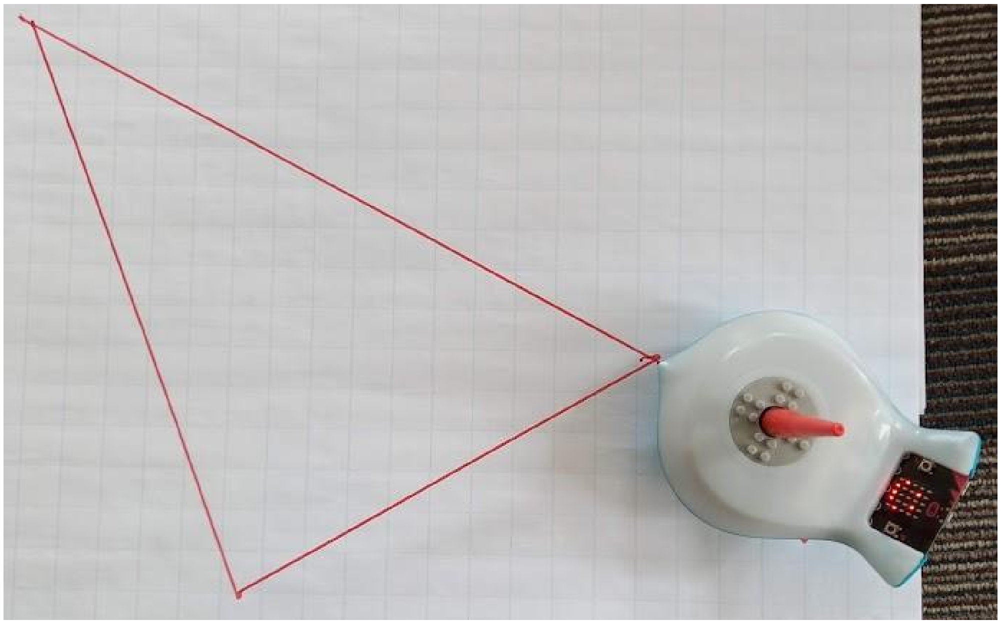
Screenshot of Sample Codes for an Equiangular Triangle



During the evaluation phase, I evaluated the process of each student in accomplishing the given learning activity based on the observation rubric for achievement of learning activities (see table 1). On the first session, the two students achieved the learning activity (coding their robots to draw an equiangular triangle) at level two. Achievement of learning activity at level two means that “Student understands and completes the learning activity with lot of teacher’s helps”. Students’ learning activities achievement levels during session two were higher (level 3) than those of session one (level 2). However, achievement levels during session two were roughly the same as those of session three (level 3). Learning activities achievement levels during session three were also almost the same as those of session four (level 3). Achievement of learning activity at level 3 means that “Students understand and complete the learning activity with minimal teacher’s help”. Figure 8 show a triangle which was drawn on the last session by a Finch robot coded by one the students with very minimal teacher’s help. During the study period, students were not able to reach the highest level (level 4) of achievement which would mean that “Student understands and completes the learning activity without the teacher’s help”. Students loved participating in the learning activities (challenges). For example, at the end of one session I asked, “How was the challenge of drawing the right triangle with the Finch robot?” Student3 said “I love it.”, and Student5 said “I like it.” In general, based on observations of students’ participation and achievements of the learning activities, I can conclude that, students’ math self-efficacy (particularly geometry) increased as the days went on.

Figure 8

A Triangle Drawn on the Last Session by a Student with Very Minimal Teacher's Help



Discussion

One of the challenges which hinder many people from joining STEM programs in college and STEM related jobs in their poor mathematics achievement in middle or high schools. Use of educational robotics in mathematics education is a new teaching technique which seems to help to improve students' mathematics achievement and self-efficacy. The purpose of this study was to answer the following questions (1) How the use of Finch Robot 2.0 in teaching geometry to middle school students affects their mathematics self-efficacy? (2) How the use of Finch Robot 2.0 in teaching geometry to middle school students affects their mathematics achievement? (3) What is the relationship of student's self-efficacy in mathematics and their achievement in mathematics?

How the use of Finch Robot in Teaching Geometry Affects Students' Math Self-efficacy?

Analysis of Variance (ANOVA) of the math self-efficacy survey data suggests there was a negative relationship (F (1, 4) = 35.41, p = .009) between use of the Finch robot in teaching mathematics and students' math self-efficacy. The descriptive statistics show that pre-test mean score of students' mathematics self-efficacy was higher (M_1 = 3.17) than the mean score of the post-test students' mathematics self-efficacy (M_2 = 2.94). This seems to suggest that students' math self-efficacy may have decreased as the result of using Finch robot to learn geometry. The result rejects my first hypothesis which stated that, after participating in the study program, students' self-efficacy in mathematics will increase. Although I did not expect this result, it is not surprising. Few other studies have reported similar findings. For example, previous studies findings suggested that use of robots for teaching mathematics had a negative effect on students' interest in mathematics (Alfieri et al., 2015; Conrad et al., 2018; Dohn, 2020). However, other researchers have found that, use of educational robotics in teaching mathematics has positive effect on students' interest on mathematics (Ching et al., 2019; Palmér, 2017).

Surprisingly, result of analysis of my qualitative data from observation of learning activities, contradicts the quantitative data results presented above. Finding based on qualitative data shows that, students' math self-efficacy increased as the days went on.

How the Use of Finch Robot in Teaching Geometry Affects Students' Math Achievement?

Results of the Math Achievement tests shows that, mean students' mathematics score in the pre-test was higher (M_1 = 52.5) than the mean score in the post-test (M_2 = 42.5). This suggest that, in general, students' scores on the mathematics achievement test decreased after their use of Finch robot in learning geometry. However, results of ANOVA show a nonsignificant within-subject effect (F (1, 4) = .314, p = .614) of using Finch robot to teach geometry. This suggests that I neither accept nor reject the alternative hypothesis which sated that, after participating in the study program, students' achievement in mathematics will increase. Again, this is not surprising, because some previous studies have reported that, use of robotics in mathematics education has negative or no effect on students’ mathematics achievement (Lindh & Holgersson, 2007; Walker et al., 2016). Contrary to these findings, a number of researchers have found that, use of robotics in mathematics education have positive effect on students’ mathematics achievement (Alfieri et al. 2015**;** González‐Calero et al., 2019; Muñoz et al., 2020; Palmér, 2017).

Again, the qualitative data from observation of learning activities, contradicts this finding of quantitative data about students’ math achievement. Finding based on qualitative data shows that, students’ achievement of learning activities at the beginning of the study was lower (level 2) than achievement at the end of the study (level 3).

What is the relationship between student’s math self-efficacy and their achievement?

The ANOVA of students’ math self-efficacy scores and math achievement show a nonsignificant relationship between the two variables, $F(1, 4) = .286$, $p = .63$. This result suggests rejection of my third alternative hypothesis which stated that, there will be a significance positive relationship between students' mathematics self-efficacy and their mathematics achievement. This result is contrary to findings in other studies which did not involve use of educational robotics where it was found that, students’ self-efficacy has a positive significant relationship with students’ achievement (Bresó et al., 2011; Britner & Pajares, 2006a; Kaya & Bozdağ, 2016).

Finding from analysis of qualitative data which I obtained through observation of learning activities, seems to support the above finding from quantitative data. For example, a student who obtained very low scores on both mathematics achievement tests, completed the learning activities, and seemed to have high self-efficacy in doing so.

Limitations

This study faced several limitations. The first limitation was small sample size which may have affected the results of the study. When I was planning the study, I expected to get more than ten students. But I ended up getting only six participants for the study. Moreover, out of them, two students did not continue participating through the end of the study. They only participated in one or two sessions, then stopped coming to the summer camp because their parents had other plans for them during the summer. The small sample size of the study may have negatively affected result of the quantitative data.

Another limitation of the study was short time for the study. In each week of the six weeks of the summer camp, there was only one day per week on which I was supposed to conduct my study. And, on this one day, I only had one session which lasted only 40 minutes. This time was not enough for students to complete the learning activities because it involved rewriting codes and rerunning them several times before getting it right. For instance, in one of the four sessions some of the students did not complete the learning activity. They had to complete it during lunch time because they were normally finishing eating their lunches early. This pause in the completion of the learning activity may have affected their level of achievement of the activity.

The last limitation of the study was inconsistent attendance of the students. Three of the four students whose data are included in the analysis of this study missed a session. Missing a session may have caused students to forget what they have learned in the previous session. Hence reduced their math self-efficacy and achievement.

Generally, these limitations may have negatively affected the findings of the study. So, because of these limitations, the findings of this study may not provide the true effects of using Finch robot to teach mathematics on students' self-efficacy and achievement.

Implications

The findings of this study have implications on teaching and learning mathematics, and future research about the use of robotics in mathematics education. The implication on teaching and learning is that, use of Finch robot in mathematics education, may or may not help to improve students' mathematics self-efficacy and achievement. Implication on future research is that more research about the use of Finch robot in mathematics education need to be conducted to provide clear knowledge of its effects on students' math self-efficacy and achievement. Moreover, use of a big sample size is vital for the findings of a study to be reliable.

Conclusion

Analysis of the quantitative and qualitative data of this study revealed conflicting findings. Analysis of the quantitative data showed that used of Finch robot in mathematics education in middle school lowed students' math self-efficacy and achievement. But analysis of the qualitative data revealed that students' math self-efficacy and achievement increased as they were using Finch robots in learning mathematics. Both quantitative and qualitative data of the study suggest that students' math self-efficacy may have no substantial positive or negative effects on students' achievement.

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Appendix 1

Sample 5E Instructional Model Lesson Plan

Teacher: Malimi Kazi	**School:**	**Date:** June 24, 2021
Subject Area: Mathematics	**Grade Level**: Middle School (6th-8th)	
Topic: Constructing different types of triangles		
Specific Objective: By the end of 30 minute lesson, students should be able to construct (draw) equilateral triangle by coding Finch Robot to draw the triangle as it moves.		
RESOURCES **Technology:** Chrome Books, Finch Robot 2.0, Math Open Reference website, **Materials:** Post-it Super Sticky Easel Pad, 25 in x 30 in, Washable Crayola Paint Brush Pens .		
STANDARDS:		
CCSS.MATH.CONTENT.7.G.A.2 Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle. **ISTE Technology Standards for Students** 1. Empowered Learner (d) Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.		
Engagement		
• The teacher shows pictures of different types of triangles and ask students to name them, and list characteristics of each type. • The teacher shows a Finch Robot and tell the students that it can be coded to move and turn in such a way that it can draw different types of triangles.		
Exploration		
• The teacher plays a video showing Finch Robot drawing equilateral triangle. • The teacher demonstrates to students how to use MakeCode website to code Finch Robot to move forward or backward and turns right or left at different angles. • The student practices what the teacher did, that is using MakeCode website to code Finch Robot to move forward or backward and turns right or left at different angles.		
Explanation		

• The teacher asks each student to use MakeCode website to code their Finch robots in such a way that they can draw an equilateral/equiangular triangle on paper pads. • The teacher asks students to explain how they coded their robots in order to draw the equilateral triangle.
Elaboration
• The teacher challenges and extend students' conceptual understanding and skills by asking students to apply their understanding of coding the Finch robot to draw another equilateral/equiangular triangle with different sides' length.
Evaluation
• The teacher guides students to assess their understanding and abilities of using Finch Robot to accurately draw equilateral/equiangular triangle. • The teacher evaluates whether students have achieved the educational objectives.