Autonomous Robotics Math Curriculum Development Using C Coding Language to Increase Student Attitudes and Learner Outcomes

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Abstract: Educational robotics is increasingly becoming incorporated into K12 instructional curriculum. The addition of autonomous robotics into mathematics lessons increases student engagement and attitudes towards robotics and STEM. This mixed methods study provides educators with an autonomous robotics curriculum, developed in C coding language, to increase learner attitude outcomes towards robotics and STEM. According to research from Vollstedt *et al*. (2007) as society progresses, students need to increase their knowledge of science, mathematics, engineering, and technology (STEM) to compete with the rest of the world and to efficiently utilize the new technologies that are introduced. This study was conducted at a STEM school in a small suburb of Boise, Idaho. Thirty-two fifth grade students participated in the study incorporating qualitative observations and quantitative surveys. The study concluded that coding using C coding language is one way of increasing attitudes towards robotics and STEM. Future curriculum development and research using autonomous robotics is needed to provide educators with tools to increase learner attitude outcomes towards robotics and STEM.

Keywords: Autonomous robotics, STEM, C coding language.

INTRODUCTION

Educational robotics is increasingly appearing in educational settings, being considered a useful supporting tool for the development of cognitive skills, including Computational Thinking (CT), for students of all ages (Ioannou & Makridou, 2018). As educators prepare students for college and career readiness, computational thinking skills, including coding and robotics, are being taught in the K12 educational environment. Educational robotics offers a possible approach to introduce computer science education at the primary level as a didactic tool to promote computational thinking (Tengler & Sabitzer, 2022).

In research from Stork (2020), 21st century competencies encompassed such basic skills as critical thinking, problem-solving, creativity, communication, collaboration, innovation, teamwork, decision-making, leadership, knowledge application, self- direction, and learning how to learn. This study challenges students to employ 21st century competencies to successfully code an autonomous robot to complete mathematical challenges. Savard and Highfield (2015) found children who are engaged in programming robots could explore spatial concepts, problem solving, measurement, geometry, and engage with meta-cognitive processes (Clements & Meredith, 1993; Yelland, 1994). Research from Benitti (2012) concluded that robotics activities have tremendous potential to improve classroom teaching.

This study recognizes the importance of teaching coding and robotics across subject areas. K12 students can utilize robotics in mathematics, physics, and English language arts (ELA). Mathematical concepts were taught with educational robotics combining computational skills with digital tools. These two components continue to increase in importance as computational thinking skills continue to grow in the K12 educational environment. This study documents the relevance of providing computational thinking skills aligned with mathematical grade level standards.

The purpose of this mixed methods study is to identify learning targets and success criteria, aligned with fifth grade math standards, for students to develop math skills through coding an autonomous robot in C coding language. The quantitative data is collected through pre and post surveys identifying attitudes toward coding and student observations. The pre and post survey data is analyzed using SPSS statistical software with a Paired Sample T Test to identify the differences in attitudes toward coding robotics before and after the study. The two research questions for this study are as follows.

1. How is the integrated robotics curriculum for students' math instruction developed to increase student outcomes?

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2. Did student attitudes toward coding autonomous robots positively increase following the mathematical robotics challenges?

LITERATURE REVIEW

Research from Barker *et al*. (2012) found educational robotics opens a door to help children learn about mathematics and scientific concepts through the practice of inquiry, as well as develop technological fluency. The autonomous robotics curriculum developed in this project provides coding access to educators to transfer to their students. Educational robotics provides a learning environment rich with opportunities for using an interdisciplinary approach to integrating many disciplines, such as mathematics, writing and language, technology, science, social studies, dance, music and art (Barker *et al*., 2012).

Robots provide an open-ended environment for teachers to develop innovative curriculum that integrates technology with different content areas (Bers & Portsmore, 2005). The autonomous robotics curriculum developed in this project can be implemented within the elementary classroom. This supports the findings from Ucgul & Cagiltay (2013) who stated in recent years, interest in using robots for educational purposes had increased.

A recent project by Nugent *et al.* (2016) delivered informal (out-of-school) learning environments, through robotics camps, clubs, and competitions, and provided robotics experiences to over 5,000 youth and 400 educators. Nugent *et al.*'s robotics project was based on a theoretical framework derived from experiential learning, which is similar to problem-based learning in that students learn concepts and principles through authentic experiences and problems, typically in small groups, and with teachers as facilitators (2016). The goal of the Nugent *et al.* project was to positively impact the youths' science, technology, engineering, and mathematics (STEM) knowledge and attitudes and to foster an interest in STEM careers (2016). Research and evaluation from the Nugent *et al*. (2016) study concluded that youth participation in robotics activities increased student STEM content knowledge (particularly engineering and computer programming), perceived problem-solving skills, and interest in engineering careers. The need for future studies implementing robotics activities in educational environments was identified in the Nugent *et al*. (2016) study.

Research from Shipepe *et al*. (2022) found Teaching robotics to primary school kids, *i.e.*, 4th–7th grade is becoming popular throughout the world as robotics is now part of most of the school curriculum. Shipepe *et al*. concluded it is important to acquire programming skills from an early age because it helps them develop computational thinking skills, creativity, logical thinking, algorithmic thinking, problem solving and innovation skills (2022).

Literature on manipulatives for elementary math learning found that the transparent nature of learning materials and direct physical interaction with these materials helped build explicit bridges between informal understanding and formal mathematical concepts and symbols (Okita, 2013). Through the robotics curriculum, in C coding language, it is projected that learner attitude outcomes towards robotics and STEM will be increased.

Robotics is a superb tool for hands-on learning, not only of robotics itself, but of general topics in science, technology, engineering, and math (Mataric *et al*. 2007). A fusion of project-based learning (PBL) and cooperative learning (CL) increases learner outcomes. Educational theorists such as Papert (1993) believe that robotics activities have tremendous potential to improve classroom teaching. According to Benitti (2012) educators generate ideas and develop activities to incorporate robotics into the teaching of various subjects, including math, science, and engineering. The authors develop an autonomous robotics curriculum, in C coding language, to be implemented by 5th grade educators to increase learner atttitude outcomes towards robotics and STEM.

Educational robotics is used both in and out of school environments enhancing K12 students' interest, engagement, and academic achievement in various fields of STEM education (Anwar *et al*., 2019). This mathematical robotics curriculum encourages students to write code in C coding language to run on an autonomous robot. Students achieve mathematical learning targets and success criteria, aligned with math standards, to increase learner attitude outcomes towards robotics and STEM.

METHODOLOGY

The purpose of this research is to write a robotics curriculum for autonomous robots aligned with mathematics standards to increase learner attitude outcomes towards robotics and STEM and provides formative assessment tools to educators. A concurrent transformative research framework design was utilized in this mixed methods study which included qualitative questions embedded in a quantitative pre and post survey to identify student attitudes towards robotics and STEM. Qualitative observation data was also collected by the researchers throughout this study. In pursuit of answering the research questions, the methodology for the robotics curriculum development, school setting, participants, research design, data collection and analysis are detailed in the following sections.

ROBOTICS CURRICULUM

This robotics curriculum is developed to identify fifth grade Idaho math standards; create learning targets and success criteria for five math topics; provide robotics challenges to assess math standards and rubrics for each robotics challenge. The success criteria are developed for basic coding, place value, decimals, graphing, and fractions.

The basic coding learning targets and success criteria allow educators to assess that students can code the autonomous robots to move forward, backward, turn in a circle to the left and right, code a servo to raise and lower the robotic arm, and code a servo to open and close the claw. Students complete the remaining learning targets when proficient in basic coding.

Place value learning targets and success criteria are developed to assess successful identification of whole numbers to billions, decimals to the ten-thousandths, and multiplication and division of decimals. Educators formatively assess place value learning targets and success criteria through the place value robotics challenges and rubrics. Place value robotic challenges include coding the robot to move number blocks to specific numbers; coding the robot to show a specific number with decimals; coding the robot to show what happens to this number when you multiply by 10^3; and coding the robot to show what happens to this number when you divide it by 10^2.

Decimal learning targets and success criteria are developed in this curriculum to guide students when learning about decimals. Students check their computation during instruction to ensure they are lining up decimals before adding and subtracting and adding additional zeros when necessary. Robotic challenges and a rubric are developed to identify student proficiency within the decimal math standards. Decimal robotic challenges include solving word problems then coding the robots a specific distance using kilometers, meters, and centimeters.

The robotics mats utilized in this curriculum are printed with a grid system labeled with numbers and letters. Graphing learning targets and success criteria guide students with identifying x and y axis points. In addition, students can identify specific coordinate grid locations on the robotics mat. Students are also able to show data through connecting ordinate pairs on the robotics mat. Robotic challenges and a rubric are developed in this curriculum to assess student math outcomes for graphing. Graphing curriculum includes placing the robot at grid location (0,0) on the mat, then coding the robot to move to specific locations on the grid mat.

The fifth math topic this curriculum assesses is fractions. Through this robotics math curriculum, students can make equivalent fractions, make equivalent fractions with least common denominators, add and subtract problems using fractions, and simplify their answers. Robotic challenges include first solving fraction word problems then coding the robots to the fraction using a yardstick.

This robotics curriculum includes rubrics, for each math topic and robotic challenge. The rubric developed in this robotics curriculum includes six areas the students align their robotics skills with. These include robot movement, coding, troubleshooting, connections to math curriculum, connections to ELA curriculum, and connections to real-world situations. The rubrics in this curriculum provide an assessment tool for educators implementing robotics in mathematics instruction.

SCHOOL SETTING

This robotics curriculum development study is conducted at a state-certified STEM school located in Eagle, Idaho, USA. The school has 797 enrolled students from kindergarten through eighth grade in a suburban community. The school is multilingual with an ethnically diverse student body. Four languages are spoken, 8% of students are gifted and talented, 6% special education, and 8% economically disadvantaged.

The researchers for this study are elementary educators at the STEM certified school where the study is conducted. The researchers have been teaching robotics in their classrooms and as an after-school robotics program for eight years.

Lower elementary students, kindergarten through 2nd grade, learn robotics using the Codeapillar, Bee Bot, Ozobots, and the Code and Go Mouse robots. Students in third grade transition to coding Lego We Do robotics and Lego Ev3 Mindstorms. By fourth grade, students begin writing code in C coding language on autonomous robots. Robotics skills continue to develop on the autonomous robots throughout fifth grade with increasingly complex robotics challenges.

PARTICIPANTS

Thirty-two fifth grade students are participating in this research study. The student's range in age from 10 to 11 years old. The majority of the students have attended the school since kindergarten. The students develop coding skills starting in kindergarten through fifth grade. Robotics and coding background knowledge includes push button coding, and block coding. The students begin writing code in C coding language in fourth grade. The participants develop robotics skills through coding in the general education classroom, in an engineering special one hour each week, and are encouraged to participate in an after-school robotics program.

RESEARCH DESIGN

The researchers observe students coding robots in C coding language to successfully complete coding challenges aligned with Idaho math standards. The researchers also develop learning targets and success criteria (Appendix A) aligned with five fifth grade math standards. These include coding robotics, place value, decimals, geometry, and fractions. Observations are collected within school hours during math instruction. Observations include completing an observation form, see Table **1**, with date, student name, and observations noted. Robotics challenges are also developed (Appendix B) for fifth grade math standards to be implemented by the autonomous robots. The robotics challenges in this curriculum use word problems and computational skills necessary to determine proficiency with the Idaho state math standards. Word problems and computational skills align with the mathematical instructional materials and pacing guides utilized in the fifth-grade classrooms. Rubrics (Appendix C) are developed for each learning target and robotics challenge for students to reference in designing successful robotics projects. In addition, rubrics are developed as an assessment tool for educators to implement formative assessments within each math topic of this curriculum.

Qualitative observations are recorded to document student success aligning Idaho math standards with

Table 1: Student Observation Form: Coding Autonomous Robots in Mathematics

Instructor: ___________________________ **Course:** ______________________________

Observer: ___________________________ **Date and Time:** _________________________

Attitude Toward Robotics

Date	Student Observed	Observations/Comments

(Source: Creswell and Creswell, 2018, p.266) coding robots. Student attitudes towards robotics are also observed during this study. The student observation form for attitudes toward coding autonomous robots within mathematics is shown in Table **1**.

Pre and post survey data, identifying attitudes towards coding robots, is analyzed using SPSS statistical software. Thirty-two fifth grade students are surveyed, using Microsoft Forms, on a five-point Likert scale, to identify correlations between coding autonomous robots to successfully complete mathematical challenges and attitudes toward coding robots. The SPSS statistical software Frequency Tables identify the Likert scale survey analysis for attitude toward coding robots with 1 the least and 5 the highest degree of attitude towards coding.

The pre-study qualitative survey samples 32 fifth grade students on a five-point Likert scale. The scores on the surveys range from 1 to 5. A score of 1 indicates the student is very uncomfortable coding a robot in C coding language. A score of 2 indicates the student is uncomfortable coding in C coding language. A score of 3 depicts the student is comfortable coding in C Coding language. A score of 4 indicates the student is somewhat comfortable coding in C coding language. Lastly, a score of 5 depicts the student is very comfortable coding a robot in C coding language. See Table **2** for the pre-study survey.

The post-study qualitative survey samples the same 32 fifth grade participants on a five-point Likert scale. The scores on the post-study range from 1, very uncomfortable coding a robot using C coding language, to 5, very comfortable coding a robot using C coding language. See Table **3** for the post-study survey.

Using a Paired Samples Test, with 95% confidence intervals, the standard deviation for the sample is 1.722. The Degrees of Freedom for the analysis is 31 and a p value <.001. Table **4** shows the Paired Samples Test.

Statistical analysis is performed, using SPSS, to identify student outcomes following coding autonomous robots in mathematical instruction. Student outcome data is collected using Microsoft Forms and a five-point

Table 2: Pre-Survey Analysis of Attitude Toward Coding

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
1	7	21.9	21.9	21.9
2	10	31.3	31.3	53.1
3	7	21.9	21.9	75.0
4	2	6.3	6.3	81.3
5	6	18.8	18.8	100.0
Total	32	100.0	100.0	

Table 3: Post-Survey Analysis of Attitude Toward Coding

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
2	5	15.6	15.6	15.6
3	8	25.0	25.0	40.6
4	9	28.1	28.1	68.8
5	10	31.3	31.3	100.0
Total	32	100.0	100.0	

Table 4: Paired Samples t-Test

		t	df	One-Sided *p*	Two-Sided *p*
Pair 1	Pre-Post	-3.491	31	< .001	<.001

Likert scale survey to identify interest in pursuing a STEM career. The data analysis identifies 56.3% of students are interested in a STEM career following coding autonomous robots in mathematics. Table **5** documents the STEM Career data.

DATA COLLECTION AND ANALYSIS

Observations are documented by the researchers through class notes, pictures, and videos. Students are observed using the engineering design process to complete robotics challenges aligned with fifth grade mathematics standards.

The students collaborate to identify the math topic. Plans are developed to successfully complete the robotics challenge. Code is written in C coding language for autonomous robots. Student code is tested to align with the math challenge. Iterations are made to the student code if necessary. Students share their successful code with classmates.

In addition to observations, pre and post surveys are implemented to identify attitudes toward coding autonomous robots using C coding language. Using Microsoft Forms and a five-point Likert scale, students rank their comfort, pre-study and post study, in the use of writing code on an autonomous robot to successfully complete mathematical challenges aligned with state standards. The survey data is input to SPSS statistical software to analyze the student responses.

The quantitative analysis in this study uses a pre and post Frequency test to identify learner attitudes towards robotics and STEM as determined by students selecting a future STEM career. Thirty-two fifth grade students are surveyed before and after the robotics curriculum implementation using a five-point Likert scale. The Frequency analysis determines 56.3% of students select a STEM career following the implementation of this robotics curriculum in comparison to 43.8% of the students selecting a non-STEM career (Table **5**).

Qualitative analysis was completed by the researchers on a shared document where observations were made during each class meeting (see Table **1**). Researchers discussed observations to correlate qualitative data with quantitative survey results. Student attitudes and comments were observed and recorded for qualitative analysis interpretation. One student commented, ""I wrote a whole code almost by myself and it worked!" Students were also observed entering the classroom each day asking, "will we be coding robots today?" Researchers also observed students clapping and cheering for each other throughout the study when the robots completed coding challenges. This qualitative data supports the post quantitative survey data identifying positive learner attitude outcomes towards robotics and STEM.

RESEARCH OUTCOMES AND FINDINGS

This study successfully identifies Idaho mathematics standards and develops a robotics curriculum for autonomous robots to align with the fifth-grade math standards. This study also provides assessment tools for educators. Students use the engineering design process to identify a math topic; solve the math equations; develop a coding plan; write robotics code in C coding language; test their robotics code on an autonomous robot; iterate their robotics code; and share with classmates successfully completed robotics challenges.

Five math topics are identified in this robotics curriculum and learning targets and success criteria are developed for each topic. These five mathematical topics are basic coding, place value, decimals, graphing, and fractions. Robotics challenges and rubrics are developed within each of the five math topics for assessing proficiency. Robotics challenges are developed in alignment with mathematical instructional materials utilized in math instruction. Appendix A identifies learning targets and success criteria for basic coding, place value, decimals, graphing, and fractions. Appendix B lists robotics challenges aligned with each math topic to identify

Table 5: Student Interest in a STEM Career

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
STEM Career	18	56.3	56.3	56.3
Non-STEM Career	14	48.8	43.8	100.0
Total	32	100.0	100.0	

proficiency. Appendix C outlines a rubric for basic coding, place value, decimals, graphing, and fractions. The rubrics are used by the fifth-grade students to evaluate robotics codes. Educators utilize the rubrics developed in this curriculum for formative assessment tools.

Observations are documented through class notes, pictures, and videos as a formative assessment tool for educators. Positive student attitudes are observed throughout the study. As students successfully complete coding challenges, positive attitudes increase. A positive correlation between successful coding and student attitude are observed in this study. Figure **1** documents the autonomous robots utilized by students in place value math instruction.

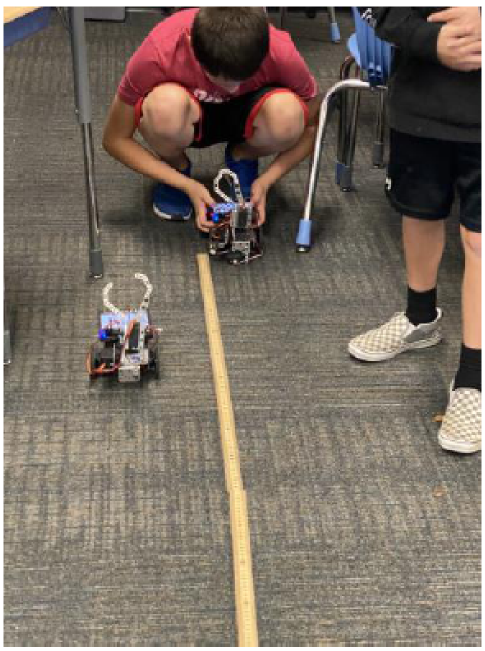


Figure 1: Autonomous Robots utilized in Place Value Math Instruction.

SPSS statistical software analyzes student pre and post survey data to identify attitudes towards coding in mathematics. The Paired Samples Correlations shows a .053 correlation in the pre and post Likert scale surveys. The One-Sided p value is .386 and Two-Sided p value is .772. See Table **6** below.

With 95% confidence interval, the Mean is -1.062, Standard Deviation is 1.722, and Standard Error Mean is .304 for the survey results. A Lower Confidence Interval of -1.683 and Upper Confidence Interval of .001 was derived from the student survey data. See Table **7** below.

The Paired Samples Test also identifies a t value of -3.491, and a Degree of Freedom of 31. The Significance in the One-Sided p test is <.001 and Two-Sided p value is .001. See Table **8**. With this qualitative analysis data, the researchers reject the null hypothesis. The students did show increased attitudes toward coding autonomous robots in mathematics.

The pre survey data identifies the comfort level of 32 fifth grade students coding an autonomous robot, using C coding language, to successfully complete challenges in Mathematics. The data shows 7 students feel very uncomfortable coding in C coding language; 10 students feel uncomfortable coding in C coding language; 7 students feel comfortable coding in C coding language; 2 students feel somewhat comfortable coding in C coding language; and 6 students feel very comfortable coding in C coding language.

Post survey data analysis in SPSS, depicts the comfort level of the same students coding an autonomous robot, using C coding language, to successfully complete challenges in mathematics following implementing the study. The data shows 0 students feel very uncomfortable coding in C coding

Table 6: Paired Samples Correlations

		N	**Correlation**	**One-Sided *p***	**Two-Sided *p***
Pair 1	Pre-Post	32	.053	.386	.772

Table 7: Paired Samples Test Confidence Interval

		Mean	**S.D.**	**Std. Error Mean**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Pair 1	Pre-Post	-1.062	1.772	.304	-1.683	-.442

Table 8: Paired Samples Test p Value Results

		t	df	One-Sided *p*	Two-Sided *p*
Pair 1	Pre-Post	-3.491	31	< .001	<.001

language; 5 students feel uncomfortable coding in C coding language; 8 students feel comfortable coding in C coding language; 9 students feel somewhat comfortable coding in C coding language; and 10 students feel very comfortable coding in C coding language.

Additionally, to identify student attitude outcomes, students are surveyed on what future career choice interests them. Following coding autonomous robots, 56.3% of students choose a STEM career. The SPSS frequency analysis suggests student attitudes toward coding autonomous robots positively increases following the mathematical robotics challenges. See Table **5**.

DISCUSSION AND CONCLUSIONS

This study provides educators with tools to implement coding and robotics in mathematics instruction. According to new research, learning with robots offers students intrinsic motivation, and invites them to investigate, foster their curiosity and imagination, to ask questions, to work in teams, to overcome challenges, to make decisions, and to be responsible for their own process (Lopez-Caudana *et al*., 2020). This study supports the need to improve educator use of robotics in mathematics instruction. According to Kopcha *et al*. (2022) codable robots provide opportunities to apply computational thinking practices within the context of mathematical instruction. Classroom educators are provided with learning targets, mathematical robotics coding challenges, and rubrics to implement math instruction with autonomous robots. In addition, formative assessments, aligned with mathematical standards, can be recorded with observations using the coding rubrics. A limiting factor of this study is the availability of autonomous robots. Educators without access to robots, or coding devices, may be limited by this study.

The findings from this study support the research from Nugent *et al*. (2016). Nugent *et al*, found youth participation in robotics activities increased student STEM content knowledge (particularly engineering and computer programming), perceived problem-solving skills, and interest in engineering careers (2016). The researchers from this study found coding autonomous robots using C coding language within math curriculum improves student attitudes towards robotics and STEM corroborating the above referenced study.

Additionally, Anwar *et al*. (2019) concluded using educational robotics in and out of school environments enhanced K12 students' interest, engagement, and academic achievement in various fields of STEM education. This study supports the research from Anwar *et al*. (2019) as evidenced by students' excitement and engagement in math curriculum and coding activities.

Okita (2013) found that the transparent nature of learning materials and direct physical interaction with these materials helped build explicit bridges between informal understanding and formal mathematical concepts and symbols. This research study confirms the Okita (2013) findings through physical manipulation and coding of robots with math curriculum.

This studies use of qualitative observations is also supported by research from Shipepe *et al*. (2022) finding the observation method can be applied in real classrooms to equip learners with robotic and other fourth industrial revolution (4IR) related skills.

The purpose of this study was to answer two research questions. Research question one identifies how the integrated robotics curriculum for students' math instruction developed increased student outcomes. The thirty-two fifth grade students participating in this research were observed to have positive attitude outcomes towards robotics and STEM following integrating the robotics curriculum for math instruction.

Second, the study identified if student attitudes toward coding autonomous robots positively increase following the mathematical robotics challenges. The mixed method study concluded through quantitative survey data and qualitative observations, students' attitudes towards coding autonomous robots positively increased upon completing the mathematical robotics challenges.

This study identifies the need to include robotics in mathematical instruction. This is a continuous study to identify student outcomes and long-term career choices influenced by robotics in mathematics instruction. This study identifies a need for future research and development of curriculum, across subject areas, that can be implemented with autonomous robots. Future research can include developing autonomous robotics curriculum throughout subject areas to increase learner attitudes towards robotics and STEM.

Appendix A

Basic Coding Success Criteria

My Learning Target:

I can code an autonomous robot using C coding language to pick up a can and place in another spot.

Success Criteria:

- ☐ My robot can move forward and backward.
- ☐ My robot can turn in a circle, both left and right
- ☐ My robot can use its servo arm to lift and place an object.
- ☐ My robot can return to home base.

Learning Progression:

- ☐ I can code the motors to move my autonomous robotforward and backward.
- ☐ I can code the servos to lift and lower my autonomous robot's arm and open and close its claw.
- ☐ I can code the motors and servos togetherby completing challenges to place an object in different spots.
- ☐ I can use motor position counter to move my autonomous robot to an exact location.

Vocabulary: backward, forward, motor position counter, motors, msleep, servos

Why is it important?

In order to successfully complete the coding math challenges in C coding language, these steps are necessary to learn.

Place Value Success Criteria

My Learning Target:

NBT.A. Understand the place value system(by coding an autonomous robot).

Success Criteria:

- ☐ I can identify whole numbers to billions.
- ☐ I can identify decimals to ten-thousandths.
- ☐ I can use powers of ten toshow multiplication and division of decimals.

Learning Progression:

- ☐ I can identify whole numbers to billionsusing an autonomous robot
- ☐ I can identify decimals to ten-thousandths using an autonomous robot
- ☐ I can demonstrate usingmy autonomous robotthat in a multi-digit number, a digit in one place represents 10 times as much as it represents in the place to its right and 1/10 of what it represents in the place to its left.
- ☐ I can demonstrate using my autonomous robotpatterns of decimal placement when a decimal is multiplied or divided by a power of ten.

Vocabulary:

compare, decimal, decimal fraction, decompose, equal to, expanded form, exponential notation, exponent, greater than, hundredth, less than, number line, one tenth of, place value, round, standard form, tenth, thousandth, unit form, word form, 10 times

Why is it important?

Coding an autonomous robotto show my understanding of place value and powers of ten helps me solve real-life problems.

Decimals Success Criteria

My Learning Target:

NBT.Bb Perform operations with decimals to hundredths(by coding an autonomous robot).

Success Criteria:

- ☐ I can line up my decimals before adding and subtracting.
- ☐ I can add additional zeros needed to add or subtract.
- ☐ I can add or subtract correctly.

Learning Progression:

- ☐ I can line up the decimals in an addition or subtraction problem, including adding necessary zeros
- ☐ I can add or subtract problems using decimals.
- ☐ I can compare decimals to determine greatest and least.
- ☐ I can identify the volume of individual layers in a figure.
- ☐ I can demonstrate addition or subtraction of decimals to hundredths by coding an autonomous robot.

Vocabulary:

decimal, decimal fraction, difference, equation, explain, expression, evaluate, hundredth, illustrate, model, recognize, strategy, sum, tenth, thousandth, unit

Why is it important?

Coding an autonomous robot to show my understanding of addition and subtraction of decimals helps me solve real-life problems.

Graphing Success Criteria

My Learning Target:

Graph points on a coordinate plane to solve real-world and mathematical problems (by coding an autonomous robot).

Success Criteria:

- ☐ I can identify points x- and y- axis points.
- ☐ I can gather data to plot.
- ☐ I can plot points on a coordinate grid.

Learning Progression:

- ☐ I can write ordinate pairs.
- ☐ I can plot points on a coordinate grid using ordinate pairs.
- ☐ I can connect ordinate pairs to show data.
- ☐ I can demonstrate my knowledge of graphing by coding an autonomous robot.

Vocabulary:

axis, coordinate grid, data, graph, slope, ordinate pair, x-axis, y-axis

Why is it important?

Coding an autonomous robot to show my understanding of graphing helps me solve real-life problems.

Fractions Success Criteria

My Learning Target:

NF.A Use equivalent fractions as a strategy to add and subtract fractions (by coding an autonomous robot).

Success Criteria:

- ☐ I can make equivalent fractions.
- ☐ I can add or subtract fractions with like denominators
- ☐ I can add or subtract fractions with unlike denominators

Learning Progression:

- ☐ I can make equivalent fractions.
- ☐ I can make equivalent fractions with least common denominators.
- ☐ I can add or subtract problems using fractions.
- ☐ I can simplify my answers.
- ☐ I can demonstrate addition or subtraction of decimals to hundredths by coding an autonomous robot

Vocabulary:

Assess, benchmark fraction, between, common denominator, decimal fraction, denominator, difference, equivalent, estimate, fraction, fractional unit, hundredth, improper fraction, like denominators, mixed number, multiples, numerator, part of a whole, produce, proper fraction, reasonable, recognize, represent, solve, sum, tape diagrams, tenth, unlike denominator, whole number

Why is it important?

Coding an autonomous robot to show my understanding of equivalent fractions and addition and subtraction of fractions helps me solve real-life problems.

APPENDIX B

Basic Coding Challenges

Directions: First, read the following problems. Then, complete these challenges by coding your autonomous robot to demonstrate the assigned tasks. It is your choice how you decide to demonstrate these challenges.

Challenge 1:

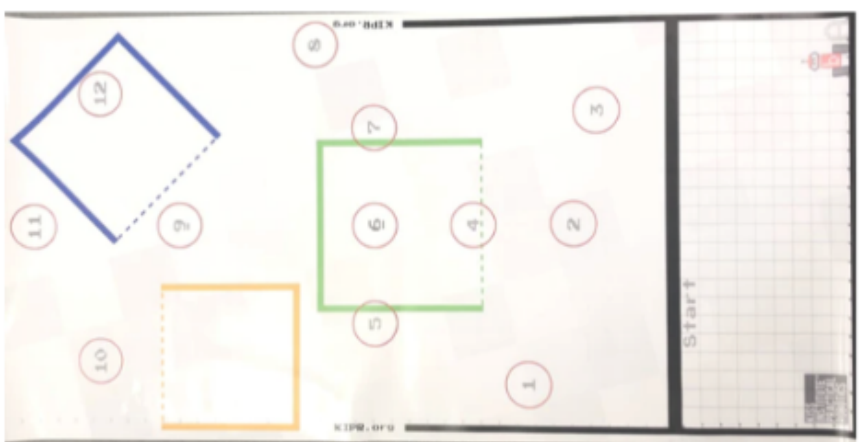
Latitude and longitude lines on a map help pinpoint locations. One partner will code a robot to move along the latitude and the other partner will move a given longitude.

Challenge 2:

Code your robot to drive the perimeter of the robotics mat. Can you drive the perimeter backward?

Challenge 3:

Code your robot to park in each colored garage on the robotics



mat.

Place Value Challenges

Directions: Complete these challenges by coding your autonomous robot to demonstrate the assigned tasks.

Challenge 1:

Code your robot to move number blocks to show the following numbers.

43.27

1,603,972.548

3.8926

Challenge 2:

1. Code your robot to show this number ~ 265.321~.
2. Now show what happens to this number when you multiply by 10^3.
3. Now show what happens to this number when you divide it by 10^2.

Challenge 3:

1. Code your robot to show this number ~ 4.2~.
2. Now show what happens to this number when you multiply by 10^3.
3. Now show what happens to this number when you divide it by 10^2.

Decimal Challenges

Directions: First, solve the following problems. Then, complete these challenges by coding your autonomous robot to demonstrate the assigned tasks. It is your choice how you decide to demonstrate these challenges.

Challenge 1:

To practice for an Ironman competition, John swam 0.86 kilometers each day for 3 weeks. How many meters did he swim in those 3 weeks?

Challenge 2:

In a paper airplane contest, Marcel's plane travels 3.345 meters. Salvador's plane travels 3.35 meters. Jennifer's plane travels 3.3 meters. Based on the measurements, whose plane traveled the farthest distance? Whose plane traveled the shortest distance?

Challenge 3:

Ava is 23 cm taller than Olivia, and Olivia is half the height of Lucas. If Lucas is 1.78 m tall, how tall are Ava and Olivia? Express their heights in centimeters.

Graphing Challenges

Name:

Directions: First, solve the following problems. Then, complete these challenges by coding your autonomous robot to demonstrate the assigned tasks. It is your choice how you decide to demonstrate these challenges.

Challenge 1:

Begin at the origin coordinates of the Botball mat (0,0).

- Move your Botball to (Q,0).
- Make a 90▪ turn to the left.
- Move your Botball to (Q,24).
- Touch Circle 7.

Challenge 2:

Demonstrate movement on a coordinate grid, by coding your Botball.

- Begin at (0,0).
- Move your Botball to the blue square.
- What are the new coordinates?

Challenge 3:

Demonstrate movement on two coordinate grids, by coding your Botball. Mark one mat A and the other mat B. Place Mat A above Mat B.

- Begin at (0,0).
- Move your Botball to the blue square on Mat A.
- Moving your Botball backward now move it to the green square on Mat B.
- What are the new coordinates?

Fraction Challenges

Name:

Directions: First, solve the following problems using common denominators found on a yardstick. Then, complete these challenges by coding your autonomous robot to demonstrate the assigned tasks. It is your choice how you demonstrate the story problem.

Challenge 1:

Mr. Sinofsky used $\frac{5}{8}$ of a tank of gas on a trip to visit relatives for the weekend and another $\frac{1}{2}$ of a tank commuting to work the next week. He then took another weekend trip and used $\frac{1}{4}$ tank of gas. How many tanks of gas did Mr. Sinofsky use altogether?

Challenge 2:

Jean-Luc jogged around the lake in 1 $\frac{1}{4}$ hours. William jogged the same distance in $\frac{5}{6}$ hour. How much longer did Jean-Luc take than William in hours?

Challenge 3:

Jing spent $\frac{1}{3}$ of her money on a pack of pens, $\frac{1}{2}$ of her money on a pack of markers, and $\frac{1}{8}$ of her money on a pack of pencils. What fraction of her money is left?

APPENDIX C

Basic Coding Rubric

Name:

Objective: How well does your robot move and show the standard?

	4	3	2	1
Robot Movement	Robot completes all movements correctly.	Robot completes most movements correctly.	Robot completes some movements correctly.	Minimal correct robot movement.
Coding	All code is written successfully to complete required movements.	All code is written successfully to complete most required movements.	All code is written successfully to complete some required movements.	Code does not meet required movements.
Troubleshooting	Troubleshooting is successfully completed when code does not compile.	Troubleshooting is successfully completed when code does not compile.	Gave up when code did not compile correctly.	Gave up when code did not compile correctly.
Connection to Math Curriculum	Exceptional demonstration of perimeter through code and robot movement.	Demonstration of perimeter through code and robot movement.	Some demonstration of perimeter through code and robot movement.	Perimeter is not demonstrated through code or robot movement.
Connection to ELA Curriculum	Exceptional demonstration of ELA editing through code and robot movement.	Demonstration of ELA editing through code and robot movement.	Some demonstration of ELA editing through code and robot movement.	ELA concepts are not demonstrated through code or robot movement.
Connection to Real-World Situations	I can fully explain how my robot and coding project fits a real-world situation.	I can adequately explain how my robot and coding project fits a real-world situation.	I know I may use this information someday, but do not know why or how.	I cannot explain how my code or robot movement connects to life outside of the classroom.

Place Value Rubric

Name:

Objective: How well does your robot move and show the standard?

	4	3	2	1
Robot Movement	Robot completes all movements correctly.	Robot completes most movements correctly.	Robot completes some movements correctly.	Minimal correct robot movement.
Coding	All code is written successfully to complete required movements.	All code is written successfully to complete most required movements.	All code is written successfully to complete some required movements.	Code does not meet required movements.

Troubleshooting	Troubleshooting is successfully completed when code does not compile.	Troubleshooting is successfully completed when code does not compile.	Gave up when code does not compile correctly.	Gave up when code does not compile correctly.
Connection to Math Curriculum	Exceptional demonstration of place value and powers of ten through code and robot movement.	Demonstration of place value and powers of ten through code and robot movement.	Some demonstration of place value and powers of ten through code and robot movement.	Math concept is not demonstrated through code or robot movement.
Connection to ELA Curriculum	Exceptional demonstration of editing and spelling through code and robot movement.	Demonstration of editing and spelling through code and robot movement.	Some demonstration of editing and spelling through code and robot movement.	ELA concepts are not demonstrated through code or robot movement.
Connection to Real-World Situations	I can fully explain how my robot and coding project fits a real-world situation.	I can adequately explain how my robot and coding project fits a real-world situation.	I know I may use this information someday, but do not know why or how.	I cannot explain how my code or robot movement connects to life outside of the classroom.

Decimals Robotic Rubric

Name:

Objective: How well does your robot move and show the standard?

	4	3	2	1
Robot Movement	Robot completes all movements correctly.	Robot completes most movements correctly.	Robot completes some movements correctly.	Minimal correct robot movement.
Coding	All code is written successfully to complete required movements.	All code is written successfully to complete most required movements.	All code is written successfully to complete some required movements.	Code does not meet required movements.
Troubleshooting	Troubleshooting is successfully completed when code does not compile.	Troubleshooting is successfully completed when code does not compile.	Gave up when code did not compile correctly.	Gave up when code did not compile correctly.
Connection to Math Curriculum	Exceptional demonstration of addition and subtraction of decimals through code and robot movement.	Demonstration of addition and subtraction of decimals through code and robot movement.	Some demonstration of addition and subtraction of decimals through code and robot movement.	Math concept is not demonstrated through code or robot movement.
Connection to ELA Curriculum	Exceptional demonstration of editing and spelling through code and robot movement.	Demonstration of editing and spelling through code and robot movement.	Some demonstration of editing and spelling through code and robot movement.	ELA concepts are not demonstrated through code or robot movement.
Connection to Real-World Situations	I can fully explain how my robot and coding project fits a real-world situation.	I can adequately explain how my robot and coding project fits a real-world situation.	I know I may use this information someday, but do not know why or how.	I cannot explain how my code or robot movement connects to life outside of the classroom.

Graphing Rubric

Name:

Objective: How well does your robot move and show the standard?

	4	3	2	1
Robot Movement	Robot completes all movements correctly.	Robot completes most movements correctly.	Robot completes some movements correctly.	Minimal correct robot movement.
Coding	All code is written successfully to complete required movements.	All code is written successfully to complete most required movements.	All code is written successfully to complete some required movements.	Code does not meet required movements.
Troubleshooting	Troubleshooting is successfully completed when code does not compile.	Troubleshooting is successfully completed when code does not compile.	Gave up when code did not compile correctly.	Gave up when code did not compile correctly.
Connection to Math Curriculum	Exceptional demonstration of graphing through code and robot movement.	Demonstration of graphing through code and robot movement.	Some demonstration of graphing through code and robot movement.	Graphing is not demonstrated through code or robot movement.
Connection to ELA Curriculum	Exceptional demonstration of ELA concepts through code and robot movement.	Demonstration of ELA concepts through code and robot movement.	Some demonstration of ELA concepts through code and robot movement.	ELA concepts are not demonstrated through code or robot movement.
Connection to Real-World Situations	I can fully explain how my robot and coding project fits a real-world situation.	I can adequately explain how my robot and coding project fits a real-world situation.	I know I may use this information someday, but do not know why or how.	I cannot explain how my code or robot movement connects to life outside of the classroom.

Fractions Robotic Rubric

Name:

Objective: How well does your robot move and show the standard?

	4	3	2	1
Robot Movement	Robot completes all movements correctly.	Robot completes most movements correctly.	Robot completes some movements correctly.	Minimal correct robot movement.
Coding	All code is written successfully to complete required movements.	All code is written successfully to complete most required movements.	All code is written successfully to complete some required movements.	Code does not meet required movements.

Troubleshooting	Troubleshooting is successfully completed when code does not compile.	Troubleshooting is successfully completed when code does not compile.	Gave up when code did not compile correctly.	Gave up when code did not compile correctly.
Connection to Math Curriculum	Exceptional demonstration of addition and subtraction of fractions through code and robot movement.	Demonstration of addition and subtraction of fraction through code and robot movement.	Some demonstration of addition and subtraction of fraction through code and robot movement.	Math concept is not demonstrated through code or robot movement.
Connection to ELA Curriculum	Exceptional demonstration of editing and spelling through code and robot movement.	Demonstration of editing and spelling through code and robot movement.	Some demonstration of editing and spelling through code and robot movement.	ELA concepts are not demonstrated through code or robot movement.
Connection to Real-World Situations	I can fully explain how my robot and coding project fits a real-world situation.	I can adequately explain how my robot and coding project fits a real-world situation.	I know I may use this information someday, but do not know why or how.	I cannot explain how my code or robot movement connects to life outside of the classroom.

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