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Impact of Robotic Challenges on Fifth Grade Problem Solving

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IMPACT OF ROBOTIC CHALLENGES ON FIFTH GRADE
PROBLEM SOLVING

by

Julie Rankin

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
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IMPACT OF ROBOTIC CHALLENGES ON FIFTH GRADE PROBLEM SOLVING

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University of Nebraska, 2019

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This action research project was designed to investigate the impact of educational robotics in a fifth grade rural classroom. The integration of science, technology, engineering, and math in education (STEM) has sparked an increase of robotics in the classroom. The purpose of the study was to determine if problem-solving skills can be impacted through continuing involvement with challenges using various educational robotics and programming tools. The study sought to answer two research questions: (1) How does the introduction of robotics challenges in a fifth-grade classroom impact students’ problem solving skills? (2) How do robotics in the classroom impact student interest and motivation? This was an action research project comprised of observations and problem-solving rubrics completed by the teacher. Additional data were collected through student interviews and problem-solving surveys completed by the participants. Data collection took place at three different times, during which five students in fifth grade were presented with various challenges throughout the school year. The goal of this study was to analyze whether or not students’ comfort level with problem-solving in robotics challenges improved after being involved in multiple educational robotics challenges, and how robotic challenges impacted students interest level and motivation.

Keywords: educational robotics, problem solving, programming, STEM, motivation
DEDICATION

This thesis is dedicated to my husband, family, and friends. Their love, support, and encouragement were instrumental in the completion of this project. A special thank you to my husband for his constant faith in my abilities and his willingness to take care of things at home while I was working on my Master in Arts degree. I also would like to recognize my two special dogs, Zeus and Zena, who were understanding and never left my side as I worked on this project.

I would also like to thank Amanda Thomas, Wendy Smith, Leen-Kiat Soh, and Guy Trianin for accepting me into the NebraskaSTEM leadership development program. I appreciate the support and guidance this team provided for all of the Noyce fellows. Their hard work and dedication to this program has made it a successful endeavor. I am excited to take the knowledge I gained from the NebraskaSTEM program and this thesis back to my school to enhance rural education.
GRANT INFORMATION

This material is based on work supported by the National Science Foundation under Grant No. 1758496. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
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CHAPTER 1: INTRODUCTION

Problem Statement

Swiss developmental psychologist, Jean Piaget believed,

The principle goal of education in the schools should be creating men and women
who are capable of doing new things, not simply repeating what other generations
have done; men and women who are creative, inventive and discoverers, who can
can be critical and verify, and not accept, everything they are offered (as quoted in
Sennett, 2004, p. 9).

Problem solving is an important skill in school, but it is also an integral part of daily life.
It is crucial for teachers to develop effective methods to improve students’ problem-
solving skills. While it is an essential skill, problem-solving is also a very difficult task
that requires stamina to persevere through failed attempts in order to find feasible
solutions. It is difficult to solve abstract problems that do not appeal to the students
background or empathy. Students need to find importance in the work they complete.
When the work is valuable to them, their motivation to do the work increases. Students
often find problem-solving very frustrating when they are not properly equipped with the
vital skills and guided practice to be successful. One of the goals of STEM education is to
present real-world problems to be solved using hands-on applications.
Purpose and Research Questions

The purpose of the study was to determine if problem-solving skills can be impacted through continuing involvement with challenges using various educational robotics and programming tools. This study sought to answer two questions:
(1) How does the introduction of robotics challenges in a rural fifth-grade classroom impact student’ problem solving skills? (2) How do robotics in the classroom impact student interest and motivation?

Methods Overview

This study was conducted using action research. Students were given three robotics challenges using three different types of robotics. Survey and observational data was collected and analyzed. In addition to the survey and observational data, students also responded to reflective questions in their journals and were interviewed after each of the three challenges. The teacher also took field notes during each challenge and scored students skills using a conceptual rubric.
Definition of Key Terms

**Computational Thinking:** a way of thinking for logically and methodically solving problems

**Constructionism:** a type of discovery learning in which the student uses prior knowledge to draw his or her own conclusions.

**Educational Robotics:** robotics used to help students learn a concept related to computer science or computational thinking, as well as general problem solving skills

**Robotics Challenges:** tasks given to students to help them get more familiar with robots and programming.

**STEM:** integration of science technology engineering math
CHAPTER 2: LITERATURE REVIEW

Overview

Motivating students to be interested in robotics and programming can be a difficult task. Finding ways to help them to develop the stamina to persevere when the problem-solving path is also complicated and uncertain. Limited research has been conducted on the effects of educational robotics on problem solving. Even more limited is the recent research about the latest robotics such as Sphero, Dash and Dot, and Makey Makey. The following studies show that students’ problem-solving skills can be improved through carefully planned educational robotics and programming challenges. This strategy builds on students’ natural curiosity to explore the world around them. These studies are organized around three major themes: theory of constructionism, problem-solving, and increasing motivation for programming.

Theory of Constructionism

Constructionism is both a theory of learning and a strategy for education (Kafai & Resnick, 2012). It builds on the “constructivist” theories of Jean Piaget, asserting that knowledge is not simple transmitted from teacher to student, but actively constructed by the mind of the learner (Kafai & Resnick, 2012).

Constructionism has articulated a more distributed view of instruction, one where learning and teaching are constructed in interactions between the teacher and students as they are engaging in design and discussion of learning artifacts (Kafai, 2006). Children possess a natural curiosity to learn about the world around them and it is important to nurture that curiosity. The theory of constructionism supports this natural curiosity by
providing guidance in real-world opportunities for students to design and build in a collaborative environment.

Sullivan and Heffernan (2016) conducted a systematic review of studies which examined other studies involving the use of robotics construction kits to look for themes, models, and a learning progression in the school classrooms. Most students begin solving problems by using trial and error methods. The results of this study showed that by using robotics, there was a progression in computational thinking from simple sequencing abilities, to more advanced reasoning abilities, and finally to improved robotic systems understanding (Sullivan, & Heffernan, 2016).

Atmatzidou and Demetriadis (2017) described another method called CPG+ (Collaboration, Problem, Game or Competition, + supplementary teachers’ supportive interventions) that questioned how computational skills and problem solving skills were developed based on the amount of guidance provided. The group with strong guidance outperformed the minimal guidance group, but all students showed improvement in regard to computational skills and problem-solving skills at the end of the robotics activities.

Constructivist approaches to learning strive to create environments where learners actively participate in the environment in ways that are intended to help them construct their own knowledge, rather than having the teacher interpret the world and insure that students understand the world as they have told them (Jonassen, 2000). Mikropoulos and Bellou (2013) also focused on a study that was based on a constructivist-constructionist theoretical model, in which students use their existing knowledge to figure out a solution to a problem. This involved two case studies showcasing the potential of educational
robotics as mindtools in the classroom. The physics case used robotics as a tool to motivate students to solve real world challenges, while the programming case presented students with a math problem and asked them to solve it on paper and with the Robolab programming. Robolab is software used to program and control RCX microprocessor embedded in the LEGO bricks. Once the program is downloaded to the RCX, the RCX can be disconnected from the computer and used independently. Robolab was designed for LEGO specifically for the school environment and differs from the Mindstorms software in the toy stores in that it has a lower entry and a higher ceiling (Erwin & Rogers, 2000). Using the Robolab increased the students’ motivation and accuracy. The authors stressed that the focus should be educational robotics in which students learn with technology instead of robotics education in which students learn from technology. It is common practice to utilize computers to search for information, write papers, and practice skills. While these are important activities, Papert (1980) believed it was more important for the student to control what the computer does in order to increase their own thinking skills.

**Problem-Solving Skills**

This potential influence of the computer on changing our notion of a black and white version of success and failures is an example of using the computer as an “object-to-think-with” (Papert, 1980). While the purpose of using robotics, programs, and computers isn’t to necessarily teach programming skills, the practice with these skills teaches how to find and fix mistakes. Children learn to fear being wrong and often get too
focused on being “correct”. This fear seems to hinder the problem-solving process and willingness to try finding solutions on their own.

Problem-solving skills can be taught to students. Turner and Hill (2008) conducted a study in which LEGO Mindstorms robotics were used to teach problem-solving before teaching programming. Students were asked if they believed that robotics based problems helped with developing problem-solving skills, and all respondents replied yes. Respondents further explained that using robotics provided a physical or visual representation of the problem, which allowed these students to view the problem in different ways (Turner & Hill, 2008).

Barak and Zadok (2009) also investigated how to teach problem-solving skills by observing students using Lego Mindstorm. Students were able to instinctively discover solutions by using hands-on approaches, but they had difficulty reflecting on the specific problem-solving process they used. Students progressed from a practice where they began constructing immediately using trial and error to spending more time planning before beginning construction, similar to results found by Sullivan and Heffernan (2016).

Sullivan and Lin (2012) also studied problem solving in relation to the perceptions of middle school students on the ideal science student. Each student’s idea of an ideal science student affected how they approached solving a problem. This study also noted that students simulated how they wanted their robot to move in order to help program it correctly (Sullivan & Lin, 2012). This simulation helped the students understand what was needed in order to resolve problems and program their robot correctly.
In order for young people to be prepared for adult life, they need to be comfortable in working collaboratively to address the kinds of problems they will face in the 21st century (Kuhn, 2015). Collaboration and peer interaction are important when teaching problem-solving skills, but according to Kuhn (2015), effective collaboration requires participants to directly engage one another’s thinking. Fawcett and Garton (2005) recognized that when students worked collaboratively with students of differing abilities and opinions, they obtained a higher performance output than when working individually.

Using engineering projects, Jordan and McDaniel (2014) showed that their peers influenced fifth grade students when they were faced with a collaborative task. Students receiving supportive responses from their peers were able to manage their uncertainty, often resolve it, and move on. Whether or not students received supportive responses also affected their level of participation and subsequent attempts to manage uncertainty. Factors, such as sharing the same uncertainty and having good social relationships, increased the chances of receiving supportive responses to uncertainty.

**Increasing Motivation For Programming**

STEM education is necessary to pique interest and motivation for youth to pursue anticipated future careers. Robotics are an engaging way for students to improve their critical thinking skills. Programming is an essential skill in robotics, but many students are not interested or motivated to pursue it. Barnes & Brooks (2018) conducted a study regarding the stereotype that computer scientists are mainly white and Asian men. This stereotype discourages many female and underrepresented minorities (URM) from
enrolling in computer science classes because most of the teachers are white and Asian men. The study suggested that recruiting more female and underrepresented minority teachers encourages students of all backgrounds to gain interest in computer science and programming classes. Computer science or programming is also not required or even offered in many schools, and therefore many students do not know much about programming. It is difficult to garner interest from students without exposure to computer science and programming,

Witherspoon, Schunn, Higashi, and Shoop (2018) investigated how programming content in a virtual robotics curriculum helped students learn and improve their motivation in middle school classrooms. Students were introduced to dynamic problem solving tasks through visual programming language to logically focus and respond to changing tasks. Findings showed that explicit programming instruction improved transferrable programming knowledge, but motivation tended to decline. Explicit instruction is more about following procedures and learning passively rather than actively being involved in the learning. This decline may have been due to the short length of the study, which is a concern of this study.

The lack of motivation for students in robotics is a major concern. Rusk, Resnick, Berg, and Pezalla-Granlund (2008) suggested that students should be introduced to robotics technology and concepts in a variety of formats. Some ideas were to concentrate on the themes instead of the challenge, combine art and engineering, include storytelling, and focus on exhibitions instead of competitions. Results showed that tailoring the tasks to a wider range of students’ interests increases motivation and broadens participation. In my own classroom, I have observed some students prefer writing and art, some excel in
the research, while others love doing the actual coding and tinkering. These experiences align with recommendations made by Rusk et al. (2008). There are some challenges with this approach, such as extra preparation, planning, engagement, and guidance. Even though this article was written in 2007 and used the technology, PicoCricket, it provided great ideas for encouraging more students to get involved in robotics, programming, and STEM education. Although this research was decades old, it still highlighted the benefits of robotics in education. Technological advancements are being made at such a rapid rate, that it is difficult to keep up.

H&S Electronic Systems is another robotics package investigated by Stergiopoulou, Karatrantou, and Panagiotakopoulos (2017) for motivational benefits. Students were given a diagnostic questionnaire and programming worksheets of increasing difficulty. The goal was to introduce students to programming and identify if a connection was made to STEM subjects. The results supported an increase of interest in programming and a general understanding of a connection to STEM subjects.

Motivating students to get involved in robotics can potentially lead to more endurance in problem-solving. Promising evidence shows that problem-solving skills can be improved through educational robotics by finding creative methods to motivate students to get involved, but more lengthy research is required to study the full impact of educational robotics.

Summary

This literature review focuses on three main themes: constructionism, problem solving and increasing motivation for programming. Constructionism is based on the idea that students learn by actively constructing using their natural curiosity and prior
experiences. When this natural curiosity is permitted in a constructive way with guidance from the teacher, it can be a gateway to unlocking student potential. Problem solving is a difficult skill that students need to practice with a mindset in which failure is just another part of the process. Robotics and programming could potentially be a motivating path for students to practice their critical thinking skills in an engaging way.
CHAPTER 3: METHODS

Overview

This was an action research study about the impact of educational robotics in the classroom and focused on following two questions: (1) How does the introduction of robotics challenges in a fifth-grade classroom impact students’ problem solving skills? (2) How do robotics in the classroom impact student interest and motivation? In order to answer the proposed research questions, a survey was utilized in which students rated their experiences in respect to problem-solving after they completed each of three robotics challenges. Students also responded to reflective questions in a journal and were interviewed about their experience after each challenge. The teacher recorded observations of students’ problem-solving strategies and struggles in a journal and created fieldnotes during the challenges.

Context of the Study

This study was conducted in a small rural community during the spring semester of the 2018-2019 school year. There are two schools, a public and a private, in this community of less than 500 people. The public school serves predominantly white students. Population of students in the public district has remained steady over the past five years, but had been previously declining. This student decline prompted a merger with a nearby district five years ago. The district now encompasses approximately 273 square miles and serves four communities. There are two school sites that house PK through fifth grade, with one site also housing the middle school and the other the
housing the high school. Total student population in the district was 235 with fifty-five percent receiving free and reduced lunches.

There were 51 students at the site where this study took place. Class sizes vary from 4 to 8 students per class in the elementary. Paraprofessionals are available to assist the teachers and students. First and second grades are taught together by one teacher in a combination classroom, as well as third and fourth grades.

The fifth grade is in a single classroom in which I teach the core subjects of reading, language, math, science, health, and social studies. I grew up in this community and therefore I am very familiar the school and the families. I received my BA from University of Nebraska in Lincoln. I have been teaching in this school for twelve years, and 7 of those years I taught 5th and 6th grades in a combination classroom. For the last 5 years, I have taught 5th grade. I am currently working on getting my Master of Arts degree in STEM education and will graduate in August 2019.

Each robotic challenge took approximately 2-3 weeks. Time to work on the robotics challenges was mostly given during science class the last period of the day. These challenges were designed to integrate STEM, therefore students worked on them during other classes as well. Students composed stories for two of the challenges, consequently students worked on these challenges during reading and language time.

**Participants**

The sample for this study includes my small fifth-grade class of five total students at a rural school. The class consisted of five high-achieving students, including one boy and four girls. All students were interviewed after each challenge due small number of participants. Each of the participants had some experience coding on a computer. Two of
the participants reported having had experience coding with LEGO Mindstorms at a summer camp. A colleague collected parental consent for research participation. The researcher requested assent from the students and all students assented to take part in this study.

Due to the small size of this group, making generalizations to other contexts and larger classes will be limited. One positive aspect of the small number of participants is the allowance for close observation of individual problem-solving skills and progression of stamina throughout the study.

Data Collection

This action research used both survey and observational data. In addition to the survey and observational data, students also responded to prompts in journals and were interviewed after each challenge. The teacher also took field notes and scored students using a conceptual rubric for problem solving with robotics.

Student Surveys

Self-assessments were given in the form of surveys (see Appendix A) to the students after each of three challenges. These surveys focused on the students’ feelings about each challenge, as well as their processes to work through each challenge.

Student Journals

Students also responded to journal prompts (see Appendix B) with written reflections after each of three challenges. These reflections described how the students felt about each challenge, specific frustrations or successes relating to the challenges, ideas that worked and those that did not, and suggested strategies that might be successful next time.
**Student Interviews**

Individual interviews, which took 15 minutes, were conducted with students after each of three challenges to gain more insight into students’ problem solving strategies, as well as frustration and successes. These interviews were intended to help me understand what the students were thinking while working on the challenges.

**Pictures and Videos**

I took pictures and videos of the students while they were planning and working on the challenges. Some of the videos were used to rewind and view the test runs, so students could troubleshoot and fix things that were not working correctly. I also took pictures of students’ planning sheets and completed codes.

**Teacher Observations**

I, as the classroom teacher, recorded detailed observations of student activity during each of the three robotics challenges. I have a personal teacher journal in which I typed thoughts and notes into 1-2 page entries several times each week. In my journal, I reflected on the impact of robotics on problem solving, and took particular note of any changes in the students’ problem solving skills and perseverance. Some notable observations included strategies used to solve problems without asking for my help, signs of frustration levels, and general levels of interest in the challenge. I also completed rubrics for problem-solving strategies based upon Polya’s stage. (n.d.). (see Appendix C).
### Table 3

**Summary of Data Collection Timeline**

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<tr>
<td>Teacher Rubric</td>
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**Data Analysis**

I used open coding on the student journals and interviews, along with teacher field notes and journals to look for common words or themes. Some of these themes I noticed were improvements, perseverance, and collaboration. The qualitative data were analyzed by studying the results of the assessments. The ratings on the student surveys were key factors in understanding students’ confidence level in their own problem-solving skills. Higher scores on the surveys indicated greater skill at problem solving, while lower scores pointed out skills that will need continued guidance for improvement. I looked for areas showing consistently low or high-scoring ratings as a class, while also scrutinizing the individual rating scores. Strategies will be developed with future challenges to guide students towards stronger problem-solving skills in areas that have low rating scores. Areas with high rating scores will be used to encourage student motivation in completing more difficult challenges.

Students written reflections were an important source of information for describing the levels of students’ frustration, interest, and motivation after doing each robotics challenge. These reflections were analyzed for common themes and other information that can be used to guide instruction. By giving the students a voice in the
types of challenges assigned, it also increased their motivation to work diligently and give their best effort.

My teacher observations and interviews with the students were also examined for themes and patterns revealing areas needing improvement. The interviews were another authentic way to gain a better understanding of how the students were feeling after completing each challenge. Informal discussions were valuable tools for assisting the teacher in improving previous challenges and creating new challenges based on student interest. This also helped build a trusting relationship between myself and the students.

The data from the survey from each challenge were sorted into tables to make it easier to look for common themes. Data from the rubric scores were organized into a table to provide a snapshot of the progression of students in the areas of creativity, iteration, initiative, and learning.

**Summary**

This chapter described the methods used to study the effects of educational robotics in a fifth grade classroom. The context of the study was described as it took place in a small rural school. The participants were five students in fifth grade. The types of data collection were student surveys, journals, and interviews. Teacher journals and field notes were also collected, as well as a scoring rubric. Data analysis was performed through careful scrutinizing of the journals and interviews to find common themes.
CHAPTER 4: FINDINGS

Overview

The purpose of this study was to answer two questions about the impact of robotics on problem-solving skills: (1) How does the introduction of robotics challenges in a fifth-grade classroom impact students’ problem solving skills?” The findings of the study suggested that student’ problem-solving skills were impacted by increased self-sufficiency, planning, collaboration, debugging and making improvements, and perseverance.

The second question this study sought to explore was (2) How do robotics in the classroom impact student interest and motivation?” The findings are organized by major themes found in the data including initiative, parental partnership, leadership, and teacher adaptations.

Each of the three robotic challenges is described first. The first challenge was to write a story and make a Treasure Map with Dash the robot. The second challenge was to create a Valentine’s Day box and connect it to a Makey Makey circuit board. The final challenge was to tell the story of a rock in the rock cycle using the Sphero robot. The findings are discussed after the challenges.

Treasure Map Challenge with Dash

I adapted a language assignment in which students composed a full circle story about a treasure map discovered by children in their grandmother’s attic. A full circle story ends in the same location where it began. The original lesson instructs students to draw a treasure map that corresponds to their story. This year, I added a robotic component to this lesson. Instead of making a treasure map on paper or the computer, I
challenged them to create a larger scale treasure map on the floor using three-dimensional props. The criteria included drawing at least one picture for a prop, building one prop out of some kind of building blocks, and designing one prop out of recyclable materials.

Next, students made a grid to use as a plan for coding Dash, the robot, through the path of their treasure map (*Figure 1*). They labeled the horizontal squares with numbers 1-18 and the vertical squares with letters A-K to use as locators in the code. Each student had an iPad, in which they used an App called Blockly from Wonder Workshop, to transfer their plan into a code. This App allows one to connect blocks of code that control Dash’s sound and movement. After coding the path, students created larger versions of their map on the floor of the multi-purpose room. Each square on their paper represented one square on the tile floor. Students measured the width of one square on the floor, which was 30 cm., and used this information to input the correct distance into the code they wished Dash to travel. Students also needed to code the angle and direction of turns, speed, and sounds they wanted Dash to make. Students used sticks to outline the path that they intended the robot to travel to help them see if their robot was following their grid plan maps correctly. The students’ props were set in locations where Dash was coded to speak, make sounds, and perform actions to match their Mystery Map stories.

*Figure 1*. Student planning grid for Dash’s path through the Mystery Map
Valentine’s Day Box Challenge with Makey Makey

The second challenge was to create a plan for a Valentine’s Day box and then create the box at home. One criteria for the boxes was to include some type of buttons in the design. These buttons would be used to connect the boxes to a Makey Makey circuit board. The Makey Makey would then be connected to a computer with alligator clips to make the boxes interactive. Since this project required completing a circuit, the material students used needed be conductive. Students drew out a plan to show their design, including where the buttons would be placed, and how the alligator clips would be attached. The Scratch 3.0 website was used to record and code sounds to be played when the circuit was completed.

Another criterion was to incorporate a scientific concept into their design. Some examples of these concepts were as follows: a pulley for the claw machine, gravity for the candy vendor machine, a mirror for reflection on the vanity, a hinged flap on the mailbox, and paper protectors for a transparent fish tank.

The Valentine’s Day boxes were displayed during Parent/Teacher Conferences. The students also presented their boxes to other students and staff on Valentine’s Day. Everyone was encouraged to try out the boxes and vote for their favorite. Although, only one person received the most votes, they all knew they were winners.

Rock Cycle Story with Sphero

The third robotic challenge was to write a story about a rock that undergoes changes in the rock cycle. This challenge required the students to do some research on the different types of rocks and clever puns to include in their stories. To make the
presentations more diverse, I assigned a different type of rock in the rock cycle for each student to begin and more than one student could not use the same rock name in their story. Students also designed a poster for their beginning type of rock and an arrow describing one process that rocks undergo. The completed posters were placed on the floor in a circle to represent the rock cycle.

A small, spherical robot called Sphero was used to represent their rock moving through the rock cycle. A website called Sphero Edu was used to type and code commands to control Sphero. The coding involved figuring out the time, speed, and angle required to move Sphero to the next desired spot on the rock cycle. Students were required to travel different paths with at least 4 movements, while telling the story of that particular rock.

**Self-Sufficiency in Problem Solving**

Students became more self-sufficient in problem solving as they worked on the challenges. Many problems arose as students were working on the challenges. These robotics and the apps used to code them were new to me. I didn’t know all the answers, which prompted students to use trial and error in order to solve problems as they arose. I was there to guide them, not supply them with easy solutions to all of their problems. The students found other ways to solve their problems, including asking classmates, searching online, and troubleshooting on their own. One problem I found with this type of discovery learning is that it takes a lot more time as opposed to just showing the students how to do everything. It did impel my students to become more self-sufficient.

In my field notes I jotted down, “Student C used the Internet to find out how to hook up the Makey Makey and use it with the Scratch 3.0 website.” Student C probably
would not have done this if I already knew how the Makey Makey worked. I also noted the following statement in my journal, “Student B was trying to record a sound and it didn’t work the first time. Student B just shook her head and tried again. Student B finally figured out that the iPad must be connected to Dash in order to record a sound, but Student B didn’t ask me for help.”

During the first challenge, Student E was not very willing to try figuring out how to use the Scratch 3.0 website during the Makey Makey Rock Cycle Challenge. Student E noted in the student journal, “I wish we could just use Scratch Jr. because I know how to use it.” Student E did comment in the interview, “That using Scratch 3.0 was not that hard after practicing on Scratch Jr.” Throughout the study, student E progressively became more willing to get out of the comfort zone and try new things.

The three robotics challenges helped students to become more self-sufficient as the students knew they could not just rely on the teacher to tell them exactly what to do. The increased self-sufficiency was evident when students began searching for answers on the Internet and troubleshooting on their own. Students initially refusing to try things on their own increasingly became more willing to attempt to figure out new things. This self-sufficiency contributed to the success of the challenges.

**Planning**

The study suggested that students saw the importance of taking more time to plan when solving problems with robotics. One consistent theme I observed and took note of in my journal was, “Students spent more time planning after the initial challenge with the Dash and Dot robots.” In my teacher journal I also recorded, “I could have required that students spend more time in the planning stage for Treasure Map with Dash, but I like
that this challenge helped my students to see the benefits of planning. Increased planning time definitely shortened the time it took to get Dash through the maps successfully.” The results of the student surveys showed that the numbers of students strongly agreeing with creating a written plan helped them solve the problem increased after the first challenge (Figure 2).

This planning included physically simulating the code before testing it with the robots. The robots for the challenges in this study were loaned from our local Educational Service Unit (ESU). Only two Dash and Dot robots were available for students to interact with, which meant students had to take turns recording their stories, coding, and testing their codes. This allowed more planning time for the last students to test their robots. The detail of the plans and the time spent planning increased with each student as they took turns completing the Treasure Map Challenge with Dash. The first student took 25 tries, and the number of attempts per student progressively declined with the last student completing the challenge successfully on the first attempt with Dash. Student D responded in her journal, “I think it helped that I was one of the last ones to test my Dash robot. I got to see the problems that others had and learn from them. I added more measurement and turn information to my plan to help my coding. I also used my plan to walk through my path before I tested my code with Dash.”

Successful problem solving requires careful planning. The importance of planning was included in my observational notes as well as on the student surveys and student journal entries. At first, students wanted to just rush into using the robots with the mindset that they could easily achieve success. This assumption was refuted during the
first challenge. Consequently, students were much more willing to take the necessary time to plan before trying anything with the robotics.

\[\text{Figure 2. Student survey question number 2 results from each challenge.}\]

**Collaboration**

Increased collaboration was an important factor that impacted students problem solving. The three robotic challenges provided many opportunities for students to collaborate. The first challenge with Dash and Dot included only two robots. Therefore, students had to take turns using the robots. The amazing thing about this was that all the students ended up helping each other solve problems that arose and making adjustments.

This collaboration was very productive as the students used their own experiences with the robots to help each other. Student A noted in her journal during the Dash Challenge, “Student D helped all of us by walking through the mystery map course as we read our code from the iPad.” Simulating the code and physically walking through each command calmed frustrated students and helped students to be successful with the Dash Mystery Map Challenge faster than when the first student made attempts without the physical simulation.
During the Makey Makey Valentine’s Box Challenge, student C was the person to go to for assistance. This was a great confidence builder because student C is not usually the student others go to for help. Student E stated in an interview, “I’m so glad that student C helped me figure out what was wrong with my circuit before other classes came to see our Valentine’s Day boxes.”

Some of the students’ comments as I conducted interviews included, “I like it when my classmates help me with ideas,” “It helped to work together and try to figure out solutions to problems,” and “By the help of good STEAMERS you can succeed!”

(Figure 3)

Figure 3. Student collaboration helping Dash through the Mystery Map Challenge.

The results on question nine of the student survey showed that the numbers of students strongly agreeing with “Preferred working with a partner” actually decreased as the challenges were performed. After discussing this question during my student
interviews, I found that the students wanted a chance to create their project individually, while still cooperating with others to collectively problem solve (*Figure 4*).

*Figure 4.* Student survey question number 9 results from each challenge.

The collaboration observed during the three challenges was very rewarding. Teachers envision an environment where students are kind, cooperative, and productive. While my teacher observations of this collaboration was really great, it was even better to read journal entries and hear the students recognizing the importance of helping each other. Collaboration is a huge step in problem-solving growth students.

**Debugging and Making Improvements**

Making improvements and debugging are essential problem-solving skills. Debugging is also an important computer science skill. When asked in an interview about an improvement, student B replied, “I replaced two of the sparkly balls on my vanity for my Valentine’s Day box with aluminum foil to make it conductive. Then I could use that ball for one of my buttons because my first idea of using one of the knobs on the drawer didn’t work.”
Student C also recorded the following response in the journal for the Valentine’s Day box Challenge, “My sound to one button quit and I figured out that an alligator clip got unhooked. So, I had to find the problem and re-hook it up.” I also noted in my journal that, “Student C also had to extend the candy compartments to hold more candy. Student C also made a sign to put the extra candy in a bucket, if more than one piece came out.”

As students’ confidence with the robotics increased, so did their tinkering to improve their Sphero Rock Cycle projects. One example I explained in my journal was, “Student B figured out that by putting periods in the code when typing it, allowed the iPad’s “intelligent assistant,” Siri, to pause when speaking the story. Student B also had to change some words, such as “Magma Mia” to “Magma…..Me…Uh” (Figure 4). Students also came up with the idea to put tape on the floor of our classroom so the posters could stay on the floor in the same location. This solved the problem the students were having with the movement of the posters throwing their codes off.

Debugging and making improvements are important when solving problems. Things very rarely are successful in the first few attempts, so students need to be able to look back at what they have done and search for what went wrong or how it could be improved. The three robotic challenges assisted my students’ transformation from expecting the teacher to fix their problems to fixing problems on their own.
Figure 5. Student Sphero Rock Cycle code using Siri.

**Perseverance**

The robotic challenges improved students’ perseverance and ability to continue making an effort even after a previous attempt failed. I emphasized to my students this year that FAIL just means First Attempt In Learning. Perseverance is a necessary skill for success in solving problems that arise in all aspects of life.

I recorded the following conversation in my teacher journal during the Valentine’s Day Makey Makey Challenge, “Student C asked what would happen if they couldn’t get their boxes to work on Valentine’s Day when they presented them to the other students. I replied, ‘we would FAIL, which means First Attempt In Learning. Then
we will try again.” Student B also noted, “It won’t be right on the first try!” and “It can be fixed,” in her Dash and Dot Journal under the prompt “Something I learned today.” All of my students referred to the FAIL acronym in their final journal entries.

During an interview, I asked Student E how she felt while working on the three challenges, she answered, “It was a little frustrating at times, but we got through it. Robotics take a lot of patience, but the challenges turned out successful and I learned a lot.” This student made the most progress in perseverance by realizing that things might not work the first time, and that this is all right. Student E’s Dash took 25 attempts to get all the turns and distances correct. Subsequent turns by other students progressively decreased with the 5th student succeeding on the first try.

In my teacher journal I observed, “I can see that this challenge helped my students get better at persevering because they really enjoyed this project and they really worked hard. The students were not off task when I was helping other students. They worked diligently and with purpose.” In an interview, I asked Student I asked student D why she wanted to stay after school to work on getting Dash through the Mystery Map. Student D responded, “I knew Dash had to go back to the ESU and I really wanted to succeed at this challenge. Plus, I thought it was a fun project and I didn’t want to be the only student that didn’t succeed.”

I noted several instances in my notes regarding students staying in from recess, Specials (P.E, music, library, keyboarding, & guidance), and even a Jr. High basketball game. I wrote, “It is surprising that students chose to stay and work on their Dash challenge instead of watching the basketball game.” I found this unusual because normally my students beg to attend the Jr. High games.
Perseverance requires working hard, taking chances, and not giving up when things are difficult. My students displayed a determined work ethic during all three challenges. These students worked for long periods of time without losing their focus. If something wasn’t working quite right, the students just kept on troubleshooting until they were satisfied.

**Initiative**

Student initiative increased while working on the three robotic challenges. The following quote from my journal corroborates this initiative, “I am most proud of student B’s approach this week because she isn’t one to do homework without being told it is required. Student B took home the Rock Cycle coding sheet and drafted her whole story at home of her own accord.”

Students requested to work on their projects during recess and Specials (P.E., music, library, keyboarding, & guidance). They even asked to stay after school to continue working. Student A commented in her journal, “I am most proud of staying after school and finishing the Dash Mystery Map Challenge.” In my 16 years of teaching, I have rarely ever had students ask to stay after school or miss P.E. to work on assignments. Over the course of the three challenges, all of my students’ initiative scores improved on the teacher rubric (Table 2).

Student C also requested a Makey Makey for a birthday present from the parents after being introduced to the Makey Makey at school. Student C used this Makey Makey and a computer at home to record sounds and code them in Scratch 3.0. Student C asked to stay after school to fix a wiring problem. Student C’s dad had been working on it at
home with student C, but Student C was sure that Dad was telling him the wrong way to wire it. It turned out that student C was actually wiring it the correct way.

This project provided some freedom and choice in the details of the projects, which encouraged the students’ self-initiated efforts. By guiding, but not over-directing the students, I empowered them to take ownership of their projects. This ownership allowed students to use their own creativity and reinforced their desire to put in the extra time outside of class. The fact that there was a course to complete and presentations to other students also drove students to work overtime to make their projects successful. Varying the types of projects made it easier to appeal to the students’ individual interests.

Table 4

**Summary of Rubric Scores for Three Robotic Challenges**

<table>
<thead>
<tr>
<th>Student</th>
<th>Challenge #</th>
<th>Creativity</th>
<th>Iteration</th>
<th>Initiative</th>
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<tr>
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<td>Rubric Scores</td>
<td>2 3 4</td>
<td>3 4 4</td>
<td>2 3 3</td>
<td>3 4 4</td>
</tr>
</tbody>
</table>

1-Beginning 2-Developing 3-Proficient 4-Advanced
**Parental Partnership**

A high level of parental support was evident as I had parents send me texts and stop at school to thank me for exposing their child to this type of learning. With parent support, the students really did a great job of building their Valentine’s Day boxes at home. The boxes were all painted and decorated very nicely. It was very obvious that the students spent a lot of time working on them with their parents. The Valentine’s Day Box Challenge was a great way for parents to be involved with their child’s learning. I noted in my journal, “I could have required that my students do the work at school, but I like that it was something they could do with their parents. The parents got to see how their children really got involved in the project, and that critical thinking skills were involved even though it was a fun project.”

Positive parental involvement with their child’s learning benefits the students. I recorded the in my journal, “Another interesting note was the level of involvement student C displayed with this project. This student logged into Scratch 3.0 at home, recorded sounds, and coded the sounds without it being assigned.” Student C also responded in his journal, “Also me and my dad bought a Makey Makey and played with it on Scratch.” This student and his dad also worked on coding some other projects in Scratch 3.0, such as a calculator and dice.

Parents and teachers have the common goal to provide the best education for the students and can achieve this by forming a partnership based on mutual respect. Both of student C’s parents have sought me out and personally thanked me for changing the way student C feels about school. The following quote was from a Facebook post from student C’s parents, “Our child’s teacher won the Outstanding Teacher Award and we
couldn’t agree more! She is always incorporating STEM activities into her lessons and keeping student C interested in learning. Congrats Mrs. Rankin, we are so grateful to have you teach our children!” The following is another Facebook post from student D’s parents, “Student D’s amazing teacher this year! Thank you for all your hard work and dedication. We can never thank you enough.” These examples of positive reinforcement from the parents motivated me to continue providing opportunities my students to work with robotics and STEM projects.

The best learning environment involves a cooperative relationship between teachers, parents, and students. This year, I saw the highest level of parental collaboration I have witnessed in my sixteen years of teaching, as well as the positive effects this support had on the students. When parents are positive about school and show that they find value what is being taught, students are more motivated to work hard. This hard work leads to growth and success.

Figure 6. Students behind their Valentine’s Day boxes showing what place received.
Leadership

The robotic challenges involved with this study gave students several opportunities for leadership. My students mentored the younger grades pre-K through 4th, as well as the middle school grades 6th through 8th. The middle school students were definitely more hesitant to explore the robots. When my class showed the 8th grade how to use the Spheros, I took a note of an 8th grader telling her science teacher, “You know I don’t like doing things like this. I don’t even know how to make this thing do what I want it to do.” My students were patient with the older students and explained the basics of the Spheros. As a teacher, I recognize the immense value in mentoring other students and I plan to incorporate more opportunities for my future class to be leaders within our school.

Presenting the finished projects to other students and staff and demonstrating how the robots worked filled my students with a sense of pride, which encouraged my students to continue exploring the robotics with an open mind. This pride really enabled my students take ownership of their work and provided them with inspiration to do their very best. Student D describes this feeling in her journal, “Everyone in our school liked our Valentine’s Day boxes and that makes me proud.”

My 5th grade class also hosted a Forces and Motion STEM Carnival, in which my students created games for all the other students to play. Student C created a game called, Sphero Golf. The game consisted of driving the Sphero through obstacles and into a cup using the iPad and Sphero EDU App. I reflected in my teacher journal, “All of my students portrayed excellent leadership skills, but I was especially proud of student C because leadership is not his strongest quality.”
Effective leaders communicate well, which is an important problem solving skill. Leadership opportunities are a great way to build student confidence. Confident students are more willing to take chances when problem solving. Students in the 5th grade are often reluctant to take on a leadership role, especially around older students. Using activities students are interested in, such as the Makey Makey and Sphero, help to encourage them to take this leadership role and set good examples for others.

**Teacher Adaptations**

Growth is important for teachers as well as students, which influenced my decision to continue my education. My teaching has adapted and improved with the challenges and triumphs of this project. Before working on this project in conjunction with attaining my Master’s Degree in STEM Education, I thought I had to really understand any material or technology before I presented it to my students. Many of my colleagues have similar thoughts, which lead to reluctance towards implementing robotics. I have learned that STEM teaching requires the teacher to give up some of the control and allow students to discover things in their own way.

The students surprised me by doing amazing things without me knowing how to do everything first. It is still important for the teacher to have some knowledge of the technological tools, as well as being open to continue learning. The results of this project and the relationships I built with my students and their parents have motivated me to not only continue using robotics in my classroom, but to also encourage my colleagues to try robotics as well. Student E wrote in her journal, “I overcame my challenges by asking for help by my classmates and my amazing teacher!” Teachers need encouragement as well
as students, and this statement inspired me to keep providing innovative opportunities for my students.

Students have the potential to achieve even more if they were exposed to robotics before entering 5th grade. The younger the child, the more willing they are to explore and try new things without fear of failure. In my teacher journal I recorded, “I plan to build on the challenges I introduced this year and progress to incorporating more programming into my classroom.” The computer science class I took this summer provided me with a better understanding of computational thinking skills and computer science topics.

In order to justify the time these challenges required, I wanted to also incorporate content from the state standards from which I am required to teach. I was unable to find existing lessons involving robotics with 5th grade content, so I designed my own challenges. The challenges I created were great, but I did record some ideas for improvement. One idea for improvement that I wrote in my field notes was, “Allow more time for brainstorming ideas and planning.” I probably won’t require much planning for the first challenge because I do think it was important for students to see the difference planning can make.

Adapting to the ever-changing world is an essential process. As technology and problems associated with technology increase, teachers must adapt in order to prepare their students for this world. Informing and involving parents is instrumental in making this a successful endeavor. Students also need many opportunities to practice effective problem solving.
Summary

Three robotics challenges involved in the study were described in this chapter: Dash Mystery Map, Makey Makey Valentine’s Day Box, and Sphero Rock Cycle. I described five assertions pertaining to my first research question: (1) How does the introduction of robotics challenges in a fifth-grade classroom impact students’ problem solving skills? The findings of the study suggested that students’ problem-solving skills were impacted by increased self-sufficiency, planning, collaboration, debugging and making improvements, and perseverance.

I also described four assertions related to my second research question: (2) How do robotics in the classroom impact student interest and motivation?” The findings were organized by major themes found in the data including: initiative, parent partnership, leadership, and teacher adaptations. The positive findings resulting from these robotic challenges has encouraged me to continue modifying the existing challenges as well as including more robotics challenges for my future classes.
 CHAPTER 5: DISCUSSION AND CONCLUSIONS

Overview

Overall, this study suggested that: (1) The introduction of robotics challenges in a fifth-grade classroom does facilitate self-sufficiency, planning, collaboration, debugging and making improvements, and perseverance; (2) Robotics in the classroom increases student initiative, leadership, teacher adaptations, and parent support. These findings had positive impact on fifth grade problem solving.

Discussion

Students with self-sufficiency skills are better equipped to solve problems. My research, just like Jonassen (2000) found that using constructivist approach allowed learners to actively participate in building their own knowledge instead of just passively listening to the teacher. As the teacher, I was there for guidance and support during the challenges, but I did not tell students exactly what to do or how to do things. Students participating in this study progressively began taking more chances and attempting to figure out problems on their own or with the help of another student. Students also built upon prior knowledge and experiences to assist them with the challenges. Mikropoulos and Bellou (2013) also studied a constructivist-constructionist theoretical model, in which students use their existing knowledge to figure out a solution to a problem.

Planning is the key to successful problem solving. Similar to my study, Sullivan and Lin (2012) found positive results when students planned by physically simulating the desired movement of their robots. Since Sullivan and Lin were studying 11 and 12-year-
old boys and I was studying 11-year-old girls and one boy, this suggests that the benefits of simulating the movement of robotics is not gender specific.

My students hurried through the planning stage eagerly beginning the first challenge using trial and error, but quickly found out that this wasn’t the most efficient way to successfully complete the challenge. The progression from trial and error to seeing the importance of taking more time to plan was also reported by Barak and Zadok (2009). Barak and Zadok studied junior high students and I studied fifth grade students, which suggested that the disregard for planning spans student ages across the middle grades.

The robotics used in the three challenges provided concrete tools for students to practice the problem-solving process. Visualizing problems abstractly is a difficult task, especially for children. My findings, just like Turner and Hill (2008), found that robotics challenges provided a way to take an abstract problem or concept and provide a concrete visualization of it. I used Dash, Makey Makey, and Sphero; whereas Turner and Hill used Lego Mindstorms. This suggests many types of robotics provide the ability to provide a concrete visualization of an abstract problem.

Collaboration is not only essential in school, but also in life. Whatever the age or job, everyone will at some point have to work with others and be willing to listen to their ideas in order to come up with solutions. My observational data suggests that my students enjoyed collaborating with their peers and found this joint effort to be very helpful with problem solving. Similar to my findings, Jordan and McDaniel (2014) found that receiving supportive feedback provided motivation for students to continue working.
Jordan and McDaniel were also studying fifth graders, which suggests that peer acceptance is very important at this age level.

Throughout this study, the fifth grade students collaborated with and mentored both younger and older students. The varying ages brought a variety of skills to the group, which contributed to the success of the project. Although the older eighth-grade students were hesitant about the robotics, they were able to contribute their existing knowledge of planning, speed, and angles. The younger students were less afraid of failure, so they modeled perseverance to the fifth grade. Similar to my findings, Facett and Garton (2005) suggested that working collaboratively with students of different abilities and opinions was more productive than individual work.

Effective collaboration requires students to listen as well as communicate their ideas. When it was just my class, all five students actively participated in and contributed to the collaborative efforts of the group. Each student joined the group with varying strengths; therefore some students played bigger roles in different aspects of the collaboration during the challenges. Student A was very energetic and quick to suggest ideas, while student B took a more patient approach. Student C was the most confident with the computer and coding, whereas student D was better at the creative art and storytelling aspects of the challenges. Student E was the organized one that kept everyone on the right track. My research found that the students communicated well and directly engaged each other, similar to findings by Kuhn (2015).

Perseverance is a difficult skill to learn, especially in this world of instant gratification. My students practiced perseverance while working on the robotic challenges. Improved perseverance was exhibited by my students’ willingness to put in
extra work time, stay on task, and never give up. One connection my students made with perseverance was that the harder the work, the more rewarding the success. Students were reminded throughout the challenges to expect failure, learn from it, and continue trying other solutions. My findings, like those of Papert (1980) suggested when students are less intimidated about being wrong, they can focus more on how to get things right.

**Conclusions**

Data collected during this study suggested an increase in my students’ motivation. With increased motivation, came increased participation and learning. When students become excited about their learning, the possibilities are endless. The state science standards are shifting to a three-dimensional model in which students are expected to solve problems that demonstrate their understanding of scientific concepts and not just memorize vocabulary words. The change in standards means teachers must also change the way they teach.

Teaching means striving to find the most effective ways to promote student learning. This year, I learned that students love the type of discovery learning that the robotics challenges provided. I also learned not to let my fear of failure hinder the opportunities for my students. I just need to provide some guidance and structure as I did this year. Next year, I plan to make improvements to my current challenges, such as setting time constraints and creating better planning sheets. Improved planning on my part will help decrease the time required for these challenges, and allow time to incorporate more robotics across the curriculum to improve student motivation and learning.
The graduate classes I attended this summer, including Technology in the Classroom, familiarized me with many new types of robotics and technology sites to assist me in my endeavor to providing engaging educational experiences for my students. Another plan I have is to increase the number and variety of devices available to students at my school by applying for grants and programs. I have already received a $5,000 grant from Great Plains to purchase robotics, and I have applied for other grants as well. I have received two free Spheros from the Civil Air Patrol and plan to apply for more robotics through the same program. I also plan to loan robotics from the ESU and UNL.

I plan to share what I have learned this year about the impact of robotics on problem solving with other teachers at my school. I have already shared many robotics resources with middle school science teacher. Sharing these resources provided a natural progression for my former fifth-grade students as she teaches these students for the next three years. Next year, I plan to share robotics resources with the third and fourth grade teacher. I plan to assist in teaching the third and fourth grade students some basic robotic and coding skills. By starting students earlier, I can enhance the types of lessons and challenges I present to my fifth grade students.

The family STEM night was such a success this year that I plan to offer more family nights next year. I intend to acquire enough robotics to host a technology night as well, so parents and community members can see the impact of robotics on students. I also plan to share the positive impact of robotics on social media teaching sites. Another source I plan to share my ideas is with my Noyce teaching fellows. We have already shared STEM lesson plans and we notify each other when we find great deals on robotics and opportunities for free resources.
Limitations

Time was a limitation for this study. Inclement weather and widespread flooding caused school to be closed many days during this study, which interrupted the flow of the projects. The robots for the challenges in this study were loaned from the local Educational Service Unit (ESU) and were only available for two-week intervals. There were only two Dash and Dot robots, which required students to take turns recording their stories, coding, and testing their codes. Time was a limitation for this particular study, however, time constraints can be a positive aspect of robotics challenges when motivating students to remain on task.

This year’s state test scores would have been another way to measure student growth in problem solving, although standardized testing data with five students has very limited statistical power.

This study was situated in a small, rural elementary classroom. The student population in my class was atypical because there were only a total of five students. All of the five students were high achieving and included only one male student. While the insights might be useful for those who seek deeper understanding about robotics challenges in similar environments, this study is not generalizable beyond the unique context of this classroom. However, the qualitative data of the study allowed for better understanding students’ experiences with robotics lessons.

Future Research

As robotics are increasingly integrated into the classroom, future research has the opportunity to address the effects on problem solving more thoroughly. The increase in
robotics integration will depend on whether robotics in the classroom is a short-lived fad or is here more long term. More research on the latest types of educational robotics is also needed to more thoroughly study the effects of different kinds of robotics.

Future studies should also explore the impact of robotics in other age groups, experience levels, and types of challenges. Conducting future research with adequate numbers of robotics owned by the school would be helpful with the time constraints and number of challenges.

Some questions arose during my research. Would robotics have a similar impact on larger classrooms? How would the results have been different if I had more boys than girls? How could teachers carry over the FAIL acronym to the regular curriculum? I had an exceptionally eager and creative class this year, and I know all classes are not this way. How would the findings differ in other classrooms with different dynamics? More research is necessary in order to answer these questions.
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# APPENDIX A: STUDENT SURVEY

**Student Survey**

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<tr>
<td>I tried more than one strategy or way to solve the problem?</td>
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<tr>
<td>I was able to find solutions to this problem?</td>
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<tr>
<td>I made changes to improve my design?</td>
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<tr>
<td>I preferred working with a partner on this challenge?</td>
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<tr>
<td>I tested my prototype to see if I solved the problem?</td>
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<tr>
<td>I found this challenge interesting and would like to try this again?</td>
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</tbody>
</table>

**Rating Scale:** 0=strongly disagree 1=disagree 2=neutral 3=agree 4=strongly agree

**Scoring:**
- Sum all item ratings together.
- Higher scores indicate greater skill at problem solving.
- Lower scores indicate lower skill at problem solving.
**APPENDIX B: STUDENT JOURNAL PROMPTS**

**Student Journal Prompts**

While I worked on this challenge, I changed these parts of my plan...

I made these changes to my prototype because....

Some challenges I faced were...

What I did to overcome these challenges was...

I am most proud of this part of my work...

This challenge helped me improve my skills in....

Given more time or materials, I could improve my prototype by....

For the next challenge, I want to do better at...

How will I use what I learned next time....

Something I learned from my classmate’s today is....
# APPENDIX C: PROBLEM-SOLVING RUBRIC

## Robotics Problem-Solving Rubric

<table>
<thead>
<tr>
<th></th>
<th>1 - Beginning</th>
<th>2 - Developing</th>
<th>3 - Proficient</th>
<th>4 - Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Creativity</strong></td>
<td>Student follows a set of directions to complete a project, but did not explore new ways to alter the idea.</td>
<td>Student project is original, but mostly based off of an existing idea.</td>
<td>Student project is explored and expressed in a fairly original way.</td>
<td>Student clearly explored and expressed multiple ideas in a unique way.</td>
</tr>
<tr>
<td><strong>Iteration</strong></td>
<td>Student does not attempt to iterate or make any changes on their initial design.</td>
<td>Student attempts to make an iteration on the design and/or aesthetic of their project, but is unsuccessful in any improvement.</td>
<td>Student undertakes 1 or more iterations of their product, improving the design and/or aesthetics.</td>
<td>Student completes their product, having improved the design and/or aesthetics over time.</td>
</tr>
<tr>
<td><strong>Initiative</strong></td>
<td>Student encounters complications with frustration and does not attempt to problem-solve independently.</td>
<td>Student encounters complications with frustration, but briefly attempts to problem-solve independently before seeking assistance.</td>
<td>Student encounters complications with a positive attitude and perseveres to problem solve independently before seeking assistance.</td>
<td>Student encounters complications with a positive attitude and perseveres to problem-solve independently without needing to seeking assistance.</td>
</tr>
<tr>
<td><strong>Learning</strong></td>
<td>Student did not attempt any new learning or methodology they were not already initially comfortable with.</td>
<td>Student attempts 1 new avenue of learning for their project, but may not have been successful in its implementation.</td>
<td>Student attempts 1 new avenue of learning for their project. They demonstrate a skill they did not have at the start of the project.</td>
<td>Student attempts multiple new avenues of learning for their project. They clearly demonstrate a synthesis of skills they did not have at the start of the project.</td>
</tr>
</tbody>
</table>