COLLABORATIVE ROBOTICS, MORE THAN JUST WORKING IN GROUPS: EFFECTS OF STUDENT COLLABORATION ON LEARNING MOTIVATION, COLLABORATIVE PROBLEM SOLVING, AND SCIENCE PROCESS SKILLS IN ROBOTIC ACTIVITIES

By

Kellie Taylor

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Kellie Taylor

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The following individuals read and discussed the dissertation submitted by student Kellie Taylor, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

Youngkyun Baek, Ph.D.	Chair, Supervisory Committee
Yu-Hui Ching, Ph.D.	Member, Supervisory Committee
Jesús Trespalacios, Ph.D.	Member, Supervisory Committee

The final reading approval of the dissertation was granted by Youngkyun Baek, Ph.D., Chair of the Supervisory Committee. The dissertation was approved for the Graduate College by John R. Pelton, Ph.D., Dean of the Graduate College.

DEDICATION

This dissertation is dedicated, first and foremost, to my husband, Kelly Taylor. He has always been my most ardent supporter. His belief in me and the never ending encouragement he has shown through my post baccalaureate career has never wavered. I would also like to dedicate this dissertation to my children, Nathan, Jackie, and Katie, for whom I strive to be a role model. Not only have they demonstrated their support but they have also inspired me through their personal academic pursuits. Sacrifices have been made by these wonderful people I love. For my husband’s and children’s support, love, inspiration, company during late nights, and hours spent listening, I dedicate this dissertation to them.

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ABSTRACT

Robotics in education has shown the potential to positively benefit student learning and attitudes towards learning. However, a necessary part of robotics instruction is group collaboration. Therefore, the purpose of this study was to determine what collaborative scaffolds, or interventions, produce positive effects for students working on collaborative robotics projects for science process skills, collaborative problem solving, and motivation. In addition, the study examined the impact students' prior robotics experience had on science process skills, collaborative problem solving, and motivation. The study had two experience levels, Novice and Experienced, and three intervention conditions. The interventions included Assigned Group Roles, Classroom Discussion, and Previous Instructional Practices, which followed practices from prior years without any additional collaborative supports. All the participants experienced problem-based learning during the collaborative robotics project with collaborative scaffolds based upon their intervention conditions. The goal of the study was to identify what collaboration interventions can best support the collaborative nature of robotics instruction and create a beneficial learning environment for students by supporting student collaboration and possibly improving student motivation, collaborative problem solving, and science process skills. Furthermore, the study sought to identify impacts of different robotics experience levels to fully understand collaborative robotics projects for students as they progress through a continuing robotics curriculum. The results of the study indicated experience level and collaboration interventions can have impacts on students. Assigned

Group Roles had positive effects on students' motivation and collaborative problem solving. Experience level also had effects upon student motivation and collaborative problem solving with the Novice level demonstrating higher outcomes. A collaboration intervention was identified that has the potential to produce positive effects for students in collaborative robotics projects as well as assist classroom educators in the purposeful design of collaborative robotics projects with scientifically based strategies to improve the attitudinal outcomes for students of various robotics experience.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PICTURES

LIST OF ABBREVIATIONS

STEM	Science, Technology, Engineering, and Mathematics

CHAPTER ONE: INTRODUCTION

Robotics have been used for educational purposes since the 1980s (Bers, 2010; Castledine & Chalmers, 1993; Chambers, Carbonaro, Rex, & Grove, 2007; Papert, 1993). Educational robotics provides a fun and developmentally appropriate way to teach technology and engineering to students of all ages (Bers, 2010; Slangen, Keulen, & Gravemeijer, 2010; Sullivan & Bers, 2016). A variety of content areas, as well as social skills, can also be taught using educational robotics (Eguchi, 2012; Grandgenett, Ostler, Topp, & Goeman, 2012; Hwang & Wu, 2014; Sullivan & Bers, 2016). For the purpose of this study, educational robotics are defined as the use of robotics as a learning tool (Eguchi, 2012). Typical goals for these learning tools include; generating student interest in technology through robotic activities or lessons and engaging students in learning while teaching difficult or abstract concepts through non-traditional methods (Eguchi, 2012). Learning with robotics can facilitate student collaboration, problem solving, and critical thinking (Jordan & McDaniel, 2014; Mills, Chandra, & Park, 2013). Furthermore, robotics instruction can reflect real world research where complex problems are solved in collaboration with others (Karahoca, Karahoca, & Uzunboylub, 2011; Mills et al., 2013; Papert, 1993; Robinson, 2005). The potential benefits for educational robots move beyond classroom academics if students are able to develop real world problem solving skills (Mills et al., 2013; Papert, 1993; Sullivan, 2008). This allows them to make connections between abstract content areas through concrete hands-on robotics, negotiate and interact in collaborative problem solving environments, and develop skills that benefit them in a variety of real world situations all within the educational setting (Mills et al., 2013; Papert, 1993; Sullivan, 2008). Collaborative robotics projects have the potential to use robotics as an educational tool that combines hands-on learning in a collaborative environment and provides the opportunity for students to develop learning motivation, collaborative problem solving, and scientific process skills.

Students in the elementary engineering lab at Galileo STEM Academy currently participate in collaborative robotics projects and work in groups when designing, building, and programming robotic solutions in fourth and fifth grades. With little information available on classroom implementation for elementary students, the first year's (2012-2013) robotics instruction in the elementary engineering lab consisted of teaching students the basics of programming based upon the tutorials in the LEGO Mindstorms software. Students programmed every other class sharing eight pre-built NXT robots. The 2013-2014 school year brought additional grant funding and new opportunities for students to apply their programming knowledge to designing, building, and programming a robotic solution for a real-world problem. Students received instruction in robotics to assist with the development of basic programming skills, engineering concepts, and problem solving skills that have the potential to transfer to the general classroom.

Students begin using the LEGO Mindstorms robots in third grade by developing and practicing basic programming skills with partners using pre-built robots. Robotics act as a natural context for STEM classrooms such as the elementary engineering lab (Grandgenett et al., 2012). Robotic instruction within the elementary engineering lab progresses to more advanced programming tasks during fourth and fifth grade. Partner work during programming practice for all three grade levels provides additional feedback and peer support for the programming tasks or activities, in addition to reinforcing appropriate collaboration behaviors. Students are taught from their first time working with the robots to alternate turns modifying the program and running the robot so that both students have the opportunity to develop the basic programming skills and knowledge necessary for higher level tasks in addition to building the collaborative environment. Working with a peer is designed to reinforce the basic collaboration skills needed for working with a larger group during the collaborative robotics projects.

Students complete their first collaborative robotics project in fourth grade and a second project in fifth grade. The robotics projects have evolved over the years from 2013 to 2015. The criteria for the robotic solution can easily change from year to year, but creating the supports and scaffolds to promote maximum student benefits has been a challenging area for instructional planning. Students have difficulty working together within a collaborative project, which impacts the benefits to the students in those groups. The basic reminders of making sure everyone gets a turn building and programming has not been sufficient scaffolding in order to support students in a beneficial collaborative learning process. Identifying existing components in the instructional sequence for the robotics project may assist in determining what scaffolds, supports, or interventions would best assist the students in working successfully on a collaborative robotics project.

The collaborative robotics projects for fourth and fifth grade students use problem-based learning to aid students in developing problem solving skills and delve deeper into the engineering concepts. Typically the fourth and fifth grade students complete different projects. For example, in the 2014-2015 school year fourth grade students created robotics that could make art using a repeating pattern and fifth grade students developed a Mars rover that had to survive a ‘landing on Mars’ (a drop from a ladder onto a padded surface) and still execute the program of locating ‘water’ (blue bricks). For the purpose of the study, both grade levels were asked to complete the same robotics challenge. This school year (2015–2016) students in both grade levels were required to identify problems around the school that could be solved with a robotic solution. The project offered challenges first by identifying a problem in the school and brainstorming an idea for a possible solution. Secondly, once a potential solution was chosen, students had to design, build, and program the robotic solution. Many students in the past have had difficulty with isolating and solving problems in the design and program components of the robotic solution using a systematic scientific approach for successful completion of the project. Although the teacher provided support and instruction in regard to the design process and technical aspects over the past two years of projects, with previous classes, many students continued to use a trial and error method and lacked a systematic method for solving problems that arose during the course of the project. Even though trial and error may be a viable problem solving strategy, when used without a systematic or scientific approach, it seemed to impede student progress in developing a working design or program and, therefore, a solution to the robotics problem. In order to assist students with developing a more systematic approach to developing robotic projects and problem solving issues with the robotic solution, science process skills will be focus of the overall project and for problem solving while developing a robotic solution. For the purposes of this study, science process skills are defined as a set of skills used to systematically identify and answer scientific questions.

Science process skills and the engineering process of identifying a problem and developing a working solution in the collaborative robotics project require similar skills. In addition, students may be able to transfer those skills to the general classroom for science concepts and general problem solving.

Use of both constructivist and problem-based learning have demonstrated the potential for developing student problem solving with students creating hands-on robotic solutions to authentic problems (Eguchi, 2012; Jordan & McDaniel, 2014; Mills et al., 2013; Papert, 1993). However, the potential student benefits may not be realized if the instructional practices in the elementary lab are not supporting the students in their collaborative effort. Although robotics promotes collaboration, it is important to teach students collaboration strategies for group projects (Denis & Hubert, 2001; Jordan & McDaniel, 2014). Groups' varied success with collaborative work within the collaborative robotics project have seemed to produce a variety of student experiences with both positive and negative effects on student learning and motivation outcomes.

The problem-based nature of the collaborative robotics project allows the teacher to take on the role of facilitator and students to become the focus of the learning process. Peer interaction has been a necessary part of robotics instructions in the elementary engineering lab since problem-based robotics projects usually require group sizes of three to four students due to the number of robotics kits. Although general group rules were established in previous years to promote a respectful environment and equal participation, more structure and scaffolds in the collaborative environment may increase the student benefit of robotics instruction in relation to learning motivation, collaborative problem solving, and science process skills. With the student as the center of the learning process, students need to learn how to manage the collaboration process in order to promote similar benefits for all students. The teacher, though a facilitator, may need to provide direct instruction on collaborative strategies in order for students to learn the desired techniques. Furthermore, collaborative supports may increase the learning benefits for more students rather than simply having a few students experience satisfaction with the project. The classroom educator needs to evaluate the robotics program and determine the most beneficial supports for the collaborative nature of robotics in an educational setting.

Statement of the Problem

Elementary students work in collaborative groups during robotics instruction with the intention of improving student problem solving skills and reinforcing student engineering concepts by designing, building, and programming robotic solutions. Many students have difficulty working beneficially in groups and do not get the potential maximum benefit from working on collaborative robotics projects. While it is common for students working with robotics to have challenges with programming and the mechanics (Ucgul & Cagiltay, 2014), beneficial learning outcomes and motivational benefits from the robotics projects are also limited due to the lack of successful collaboration. Difficulties with sharing ideas and equally dividing the workload during the hands-on experience seem to limit the potential for positive benefits for students. The collaborative environment is a necessity in robotics instruction due to available resources in the engineering lab and are even recommended for group work (Eguchi, 2012; Mills et al., 2013; Yuen et al., 2014). Nevertheless, it seems group collaboration sometimes leaves students with fewer participation opportunities, less learning motivation, or with a less than enjoyable experience. Can the collaborative environment be supported to improve the learning motivation, collaborative problem solving, and scientific process skills for students?

With the use of robotics in the elementary engineering classroom for the last three years, beginning in 2012-2013, the focus has been a continuous effort to improve instructional methods and identify best practices for robotics integration at the elementary level. Although instructional supports have been implemented in the classroom in an attempt to assist the students with robotics and collaboration, a successful collaborative environment has been difficult to achieve. Learning motivation during collaborative projects may vary depending upon the group and its collaborative success. Perhaps collaboration strategies can be implemented that would promote a more productive collaboration process to aid students in achieving learning objectives and increasing benefits from the collaborative nature of robotics instruction. Eguchi (2012) notes the introduction of robots alone cannot influence students' minds or directly influence their learning; therefore changes have to be made in the learning environment to support the collaborative robotics projects. Therefore, the goal of this study was to implement collaborative instructional strategies, interventions for supporting group work to improve student motivation, collaborative problem solving, and science process skills, when designing, building, and programming robotics solutions. All the students continued with a similar past instructional sequence, but the interventions tested during the collaborative robotics project required the support of guided and deliberative classroom discussion facilitated by the teacher, or what we call, Classroom Discussion, and assigned group roles that rotated throughout the duration of the project, or, Assigned Group Roles. A group was also established that continued using previous years' instructional practices as an intervention to examine the effectiveness of prior instructional strategies, Previous Instructional Practices. No additional strategies were implemented to support this group in the collaborative environment.

Existing research indicates robotics is an appropriate tool for teaching problem solving, science skills, and improving student motivation and attitudes toward learning due to the hands-on nature and the immediate feedback on whether or not the tested solution worked (Eguchi, 2012; Jordan & McDaniel, 2014; Papert, 1993). In addition, robotics is an educational tool that is well suited for collaborative projects because of its tangible and observable nature (Papert, 1993; Yuen et al., 2014). If student benefits can be maximized by developing a supportive and safe collaborative environment for the robotics projects, more students may see benefits in collaborative problem-solving, science process skills, and learning motivation.

The ability to successfully support student collaboration in robotics groups, as well as learning motivation, collaborative problem solving, and science process skills, would fill a practical need of robotics integration into the classroom. The implementation of collaborative interventions determines if such interventions can assist students in the collaborative process and support increased student learning motivation, collaborative problem solving, and science process skills. Data gathered on collaboration interventions can provide guidelines for collaborative robotics projects and may provide a clear integrative format for educators interested in bringing robotics into the classroom and meeting similar learning objectives. Furthermore, collaborative learning is an increasingly proposed instructional method for hands-on, inquiry based, instruction. If successful collaboration scaffolds can be identified that support hands-on collaborative instructional methods, the benefits could extend beyond robotics instruction.

Research Questions

1. Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students' pretest scores?
   1.1 Are there effects of the collaboration interventions on student learning motivation, controlling for students' pretest scores?
   1.2 Are there effects of prior student experience with collaborative robotics on student learning motivation, controlling for students' pretest scores?
   1.3 Is there an interaction effect between the collaboration strategy interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students' pretest scores?
2. Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student collaborative problem solving, controlling for students' pretest scores?
   2.1 Are there effects of the collaboration interventions on student collaborative problem solving, controlling for students' pretest scores?
   2.2 Are there effects of prior student experience with collaborative robotics on student collaborative problem solving, controlling for students' pretest scores?
   2.3 Is there an interaction effect between the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students' pretest scores?

3. Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student science process skills, controlling for students' pretest scores?
   3.1 Are there effects of the collaboration interventions on student science process skills, controlling for students' pretest scores?
   3.2 Are there effects of prior student experience with collaborative robotics on student science process skills, controlling for students' pretest scores?
   3.3 Is there an interaction effect between the collaboration interventions and prior student experience with collaborative robotics on student science process skills, controlling for students' pretest scores?

Definition of Terms

***Novice* –** A novice level student is one that has basic programming skills, but has not designed, built, and programmed a robot to solve an identified problem.

***Experienced* –** An experienced level student is one that has programming skills beyond the basics of movement that includes the use of sensors and has designed, built, and programmed a robot to solve an identified problem.

***Previous Instructional Practices* –** The teaching practices that have been used in the past for the engineering classroom when implementing a robotics project.

***Classroom Discussions* –** While all classes may have a period of teacher provided direction and an opportunity to ask questions, classroom discussion provides an opportunity for students to share aspects of their projects, both successes and challenges, and seek assistance from other groups and the teacher. Furthermore, during this time the teacher models appropriate collaborative behavior and redirects students to do so as well, if necessary.

***Assigned Group Roles* –** Group roles that are developed by the teacher and implemented in a purposeful way to help students take part in all aspects of the project. There are four assigned group roles to meet the needs of the largest group size.

***Learning Motivation* –** Motivation is a learning attitude that encourages students to take an active role in and a responsibility for their own learning. This may also include developing an interest in a subject area that previously had been of little or no interest.

***Collaborative Problem Solving* –** Identifying problems and developing solutions through testing, improving, and using the collective ideas of the group.

***Science Process Skills* –** A set of skills used to systematically identify and answer scientific questions.

CHAPTER TWO: LITERATURE REVIEW

Classrooms integrate robotics for various reasons, a few of which include; teaching technology and robotics, an attempt to improve problem solving skills and attitudes toward particular content areas, and to teach engineering principles. The arguments for the benefits of robotics in the classroom continue to grow. However, integration of robotics into the formal educational setting is still relatively new and, therefore, represents an important advance in educational practices (Somyürek, 2014). In addition, much of the robotics research conducted focuses on informal programs, short time periods, and participants at middle school or secondary level (Mills et al., 2013; Mohr-Schroeder, Little, & Schroeder, 2014; Park, 2015; Sullivan, 2008). While robotics has also been shown to be beneficial in afterschool and summer programs for a variety of age groups (Benitti, 2012; Mohr-Schroeder et al., 2014; Ringwood, Monaghan, & Maloco, 2005), limited information is available for implementation of robotics in the formal educational settings. The present study has the potential to promote student benefits in the traditional elementary classroom setting, offer possible implementation solutions, and identify successful collaboration strategies for supporting the student skills required in a collaborative robotics project.

Research was examined in order to identify instructional strategies that were successful in supporting the required collaboration in the elementary engineering lab. Research suggests that collaborative peer groups promote such benefits by allowing students the opportunity to take ownership of their learning and ideas and to be active participants in the experience (Jordan & McDaniel, 2014; Mohr-Schroeder et al., 2014). However, bringing robotics into a classroom does not ensure student learning benefits without a shift in the learning environment (Eguchi, 2012). Despite the fact that many researchers discussed collaborative groups as an important aspect of the shift required for robotics projects, there was little implementation information to assist a classroom practitioner in integration in the elementary classroom (Benitti, 2012; Mohr-Schroeder et al., 2014). Hwang and Wu (2014) determined that a well-designed collaborative project should support collaboration, communication, interaction, and negotiation among the group members but provided no implementation strategies to achieve the desired student relationships. The role of the teacher and the scaffolding provided to students were viewed by many studies as critical for student success, but only basic guidelines were given for implementation, and there were few, if any, examples of scaffolding to put into practice in a classroom setting (Castledine & Chalmers, 1993; Eguchi, 2012; Kang, Choi, & Chang, 2007; Papert, 1993). Since implementation, modeling, and scaffolds are an important aspect of collaborative robotics project both for the robotics content and the collaboration skills, understanding the characteristics of the learning process, the classroom setting, and the nature of the robotics project is important for determining the models and scaffolds to put in place.

Constructivist Learning in Robotics

The student learning process in the elementary engineering lab focuses on constructivist learning with student-centered hands-on experiences that allow the students to develop critical thinking and problem solving skills. Constructivist learning focuses on the belief that students build their own meaning and learning through hands-on experiences and use of preexisting knowledge (Barker & Ansorge, 2007; Blanchard, Freiman, & Lirrete-Pitre, 2010; Chambers et al., 2007; Liu, Lin, & Chang, 2010; Papert, 1993). Although this method of learning can be a bit messy in the classroom setting, it allows students to take ownership of their learning and develop meaningful connections (Barak & Zadok, 2007; Hussain, Care, & Practice, 2006; Papert, 1993). Constructivist learning also focuses on experiential learning and solving of problems which creates connections between prior knowledge, newly acquired knowledge, and the real world (Lin et al., 2010; Papert, 1993; Somyürek, 2014). In addition, small group and student-centered tasks take priority over whole class direct instruction (Barak & Zadok, 2007; Hussain et al., 2006; Papert, 1993). Collaborative robotics projects use constructivist learning to promote the connections between prior knowledge, concrete materials, and the real world in order for students to construct new knowledge.

With constructivist learning, student knowledge is individually and socially constructed through real world experiences (Eguchi, 2012; Papert, 1993; Somyürek, 2014; Yuen et al., 2014). Learning becomes a social process, when knowledge is developed through interactions with people and artifacts (Eguchi, 2012; Papert, 1993; Somyürek, 2014; Yuen et al., 2014). The implications being that collaboration and social interactions with peers strengthen the knowledge of individual students. Building and programming robots provides a sharable product, which is also an important feature of constructivist learning (Papert, 1993). The robot not only provides further social interaction through demonstration to an audience, but also reinforces engineering skills and concepts (Barak & Zadok, 2007; Eguchi, 2012; Grandgenett et al., 2012). While hands-on learning is an important instructional goal for the elementary engineering lab, students do not perform these student-centered tasks alone. Constructivist learning promotes students actively guiding and taking responsibility for their own learning (Barak & Zadok, 2007; Bers, 2010; Somyürek, 2014), in addition, the engineering lab requires students to consider their peers' learning. Constructivist learning is appropriate for the elementary engineering lab due to the nature of the robotics project and the fact that learning promotes collaboration as students are required to work together for the length of the project.

The use of robotics in the engineering lab supports the premise of constructivist learning. Papert (1993) was the first to work with robots in the classroom and found they provided an excellent medium for constructivist learning. The hands-on nature of robotics and real world context supports the relevance for the integration of robotics into the classroom (Papert, 1993; Ucgul & Cagiltay, 2014). Robotics also generate student engagement requiring students to be active participants (Jordan & McDaniel, 2014; Papert, 1993). Student-centered robotics instruction promotes not only content specific outcomes but also promotes desirable skills for academic success and future STEM careers (Karahoca et al., 2011; Nelson, 2012). In addition to the academic and career skills, robotics may also provide students with increased confidence (Eguchi, 2012; Karahoca et al., 2011; Liu et al., 2010; Nelson, 2012; Papert, 1993). Papert (1993) emphasized that students are the agents that program the robots, and who, by doing so, gain a sense of mastery over a powerful technological tool, thus promoting student confidence. Traditional classroom settings tend to provide few opportunities for students to gain a sense of mastery over complex tools, collaboratively solve real world problems, or create a shareable product, thereby minimizing the learning experience for many students (Blumenfeld et al., 1991; Papert, 1993). While the elementary engineering lab is not a typical classroom, understanding the structure of the classroom, the nature of the learning, and the intended instructional goals, allows the classroom educator to make informed decisions in regards to instructional planning and developing appropriate supports to promote the benefits of constructivist learning.

Just as the students' roles shift with constructivist learning, to promote social interaction and hands-on experiences, the teacher's role shifts to that of facilitator. The role of facilitator requires less direct instruction on content and more modeling and instruction on appropriate forms of collaboration to support the constructivist learning, collaboration, and development of co-constructed knowledge (Eguchi, 2012; Gillies, 2014; Papert, 1993). Petre and Price (2004) described the use of robotics as a hands-on constructivist way of learning with students acquiring or building their knowledge through experimentation in student-centered tasks. With student-centered tasks, the teacher may at times need to act as expert but during robotics projects students should retain as much responsibility as possible for their own learning (Eguchi, 2012; Jordan & McDaniel, 2014; Papert, 1993). Facilitators or teachers should not provide direct solutions, but rather offer an appropriate amount of support based on observations of the needs of the students (Papert, 1993; Ucgul & Cagiltay, 2014). While facilitating collaboration and student learning, content instruction is still necessary (Barak & Zadok, 2007). The use of some direct instruction to support student-centered learning does not conflict with constructivist learning approach (Barak & Zadok, 2007; Barker & Ansorge, 2007; Papert, 1993). Furthermore, Barak and Zadok (2007) found that students were willing to have the teacher give short presentations and felt that the teacher's explanations helped them with their projects and saved them significant amounts of time and effort. A balance needs be achieved by the elementary engineering teacher by providing enough instruction to support foundational skills and avoid student frustration while still allowing the learners to construct their own knowledge through their experiences with a collaborative robotics project.

Constructivist learning requires a shift in roles for both students and teacher. Some researchers consider this a radical shift in paradigm for educators (Kang et al., 2007). Kang et al. (2007) suggest that there is an incomplete understanding of constructivist learning. They argue that constructivist learning focuses too heavily on the learning process minimizing the teaching process. Kang et al.'s support of the importance of the teacher role for successful construction of knowledge aligns with Gillies's (2014) findings that collaboration needs to be modeled and taught as well. Barak and Zadok (2007) determined that some direct instruction is beneficial and welcomed by the students. Blumenfeld et al. (1991) emphasize the amount of support required during constructivist learning for students and teachers due to the shift in paradigm from instructor to facilitator, and suggest it is a potential pitfall for constructivist learning. Identifying specific scaffolds that could support collaborative robotics project in elementary engineering would not only support the constructivist learning experience but could also support students as they work through the process of developing solutions to real world problems.

Problem-Based Learning in Robotics

The criteria for the collaborative robotics project in the elementary engineering lab focuses on identifying a problem and creating a solution. The project's emphasis on a problem corresponds not only with constructivist learning, but with problem-based learning as well. In fact, problem-based learning is based on constructivist learning in that it encourages students to activate their prior knowledge to build new knowledge by solving a problem and is especially applicable for science classrooms (Blanchard et al., 2010; Denis & Hubert, 2001; Eguchi, 2012; Somyürek, 2014). The students have to develop some type of strategy for solving the problem, even if it is trial and error, which can deeply engage the students in the learning process (Blanchard et al., 2010; Denis & Hubert, 2001). Scaffolding or instructional support may be needed to assist students in activating prior knowledge and guide students when they lose sight of the project or may not have the skills to make their big idea happen (Blanchard et al., 2010; Eguchi, 2012). Helping students to stay focused, on-task, and develop realistic goals is a critical function of the elementary engineering teacher during the collaborative robotics projects.

The elementary engineering teacher also assists students in the creation of connections between classroom learning and the real world. Papert (1993) suggests that without a connection to a problem students are experiencing disassociated learning, or instruction where rote learning does not have connections to the real world and is therefore not connected to students' experiences, which could lead to difficulty in making concrete connections to abstract subjects. The use of real world problems and hands-on experience provides an avenue for learning-by-doing and an opportunity to apply traditionally abstract educational concepts (Blanchard et al., 2010; Papert, 1993; Park, 2015; Somyürek, 2014). Furthermore, effective robotics instruction should be focused on authentic tasks and problem-based learning should mirror the unpredictable characteristics of the real world (Blumenfeld et al., 1991; Denis & Hubert, 2001;

Somyürek, 2014). Ill-structured problems mimic the unpredictable characteristics of the real world and require multiple solutions and multiple perspectives collaborating to reach the optimum solution (Somyürek, 2014). Problem-based learning involves a problem and meaningful connections that can improve student motivation and engage students in thinking (Blumenfeld et al., 1991; Denis & Hubert, 2001). Collaborative problem-based learning in the elementary engineering lab strives to combine an emphasis on group interactions to promote the building of a common knowledge through a variety of different perspectives.

The elementary engineering lab attempts to develop students' critical thinking, problem solving, engineering concepts, and develop connections between the general classroom content. The main goal of problem-based learning is to help students become skilled as problem solvers by developing an internal awareness, or metacognition, of the mental processes they use when problem solving (Barak & Zadok, 2007; Blanchard et al., 2010). Problem-based learning with robotics promotes student engagement in addition to fostering problem solving and collaboration skills (Barak & Zadok, 2007; Eguchi, 2012). The use of small collaborative groups provides students with peer support and different perspectives by interacting with the group in the problem-based learning environment (Robinson, 2005; Somyürek, 2014). Advanced robotics projects for the fourth and fifth grade students have been developed as higher level challenges and bring in additional real world applications. However, researchers have found that providing students with higher level tasks does not necessarily increase learning benefits (Blumenfeld et al., 1991). The potential student benefits may vary depending upon the characteristics of the project and instructional practices. It is important to identify what supports and instructional practices create student benefits in the elementary educational setting.

Collaboration in Robotics

Even though collaboration has been required of the students in the elementary engineering classroom, little time has been spent on developing student collaboration skills to create a successful collaborative classroom environment. Can scaffolds or supports assist in the developing safe and inclusive collaborative groups to increase the positive impacts of robotic instruction? To understand how to support collaboration, it is important to understand collaboration. Hwang and Wu (2014) define collaboration as mutual control within a group as compared to cooperation with independent control and coordination, or directed collaboration where a coordinator is in charge. Just as robotics has been used in constructivist learning, with students working together to build their knowledge of problem solving, robotics design, and programing collaboration promotes constructivist learning, assisting students in reconciling differences in understanding, and constructing a shared understanding of concepts (Denis & Hubert, 2001; Eguchi, 2012; Papert, 1993; Yuen et al., 2014). The interpersonal activity of collaborative learning becomes an intrapersonal experience when students are able to internalize the co-constructed knowledge and develop mutual understandings (Gillies, 2014; Papert, 1993; Yuen et al., 2014). Collaboration though required by necessity in the classroom can be used to benefit students.

Research demonstrates positive student benefits with the classroom implementation of collaboration and collaborative projects. According to Yuen et al. (2014), collaborative learning positively impacts student achievement, persistence, and learning attitudes. Gillies (2014) notes collaborative learning can promote student engagement and learning, evidenced by increases in student academic performance for up to three years following collaborative interventions. Eguchi (2012) confirms that educational robots can be used to encourage collaborative work among students, engagement in collaborative decision-making, and acquisition of communication skills. Research demonstrates collaborative learning, a growing pedagogical practice, is beneficial to students (Gillies, 2014; Yuen et al., 2014). However, simply adding collaboration in a classroom setting will not necessarily produce student benefits. As with other pedagogical practices, the addition of collaborative learning strategies must be done carefully, grounded in the research.

Past collaboration strategies with the elementary engineering lab consisted only of teacher established groups of mixed gender and mixed ability in an attempt to create a balance in each group. This study will proceed with more focused groupings. Both mixed and similar ability groupings have been shown to be beneficial to all types of learners within the group (Yuen et al., 2014). However, collaboration should strive for balanced groups and equal participation by all group members to promote increased conceptual learning or engagement for higher order thinking (Eguchi, 2012; Yuen et al., 2014). Though balanced groups may not be entirely possible, successful collaboration can support beneficial outcomes for students (Eguchi, 2012). In order to promote and support successful collaboration within groups, Yuen et al. (2014) identified key requirements that should be met for successful collaborative learning including effective roles, a common group goal, and individual performance assessment of each group member. Nelson (2012) identified goal management, teamwork, and work ethic as highly sought after skills within STEM careers, which would indicate successful student collaboration has the potential to prepare students academically as well as professionally. Research emphasizes the importance of the students' roles and interactions in collaborative groups arguing for the intentionality of the developed group during the projects (Yuen et al., 2014). In order to support students in these collaborative efforts, Gillies (2014) emphasized the importance of the teacher's role for effective collaboration through the implementation of classroom supports. The elementary engineering lab requires instruction beyond the engineering and robotics contents. The teacher needs to also support the required collaborative environment by implementing strategies and scaffolds for successful student collaboration.

Teachers can play a key role in effective student collaboration in the classroom through modeling and direct instruction for the desired collaboration. The dialogic talk used by teachers promotes student collaborative discussion in the classroom (Gillies, 2014; Papert, 1993). Simple questions such as "Can you explain to me what you are doing?" and "Tell me something about this?" can encourage student discussion and model collaborative skills (Eguchi, 2012). Yuen et al. (2014) examines the multiple ways in which collaboration can be successful and discovered that successful collaborative learning depends upon the focus of the discussion. Teaching students how to ask and answer questions, elaborate on responses, and use problem-solving strategies are only part of the process for the classroom practitioner (Eguchi, 2012; Yuen et al., 2014). Modeling appropriate interactions and thought processes are equally as important. Collaborative skills need to be taught and modeled by the teacher to support the development of these skills and promote the collaborative environment (Eguchi, 2012;

Papert, 1993). Since collaboration has the potential to support as well as constrain individual thinking (Mills et al., 2013), and the focus of a group can shift from finding a solution to a struggle between the group members' ideas and forms of communication (Mill et al., 2013), assisting students in developing successful collaborative skills may minimize possible negative effects from collaboration and instead promote positive student effects.

Effective collaboration has the potential to positively impact the students in the robotics project and create a learning environment in which more students experience improved learning outcomes. Robotics fosters collaboration, and robotics activities make it easier and more enjoyable for some students to participate in the collaborative process (Wainer, Ferrari, Dautenhahn, & Robins, 2010). Yuen et al. (2014) suggest students feel they learn more by working collaboratively because the group can discuss, question, work, and learn together. The impact of the social and cultural dimensions of student learning, such as collaboration, discussion, and co-constructing knowledge, cannot be ignored (Hwang & Wu, 2014; Mills et al., 2013; Papert, 1993; Slangen et al., 2010). The collaborative skills learned during robotics projects can transfer to other activities outside of robotics (Nelson, 2012; Yuen et al., 2014). This study provides students with a common goal to work towards, through identifying problems, brainstorming solutions, and developing a working robotic solution, while offering individual performance assessment of each student with a rubric that has been used for the past two years for the engineering projects. The Assigned Group Roles intervention attempts to provide participants with effective roles for equally distributing the work and experiencing the hands-on nature of robotics. In addition, the teacher role is addressed with the Classroom

Discussion groups and reinforcement of the Assigned Group Roles. The teacher models appropriate dialogue and models group discussion strategies such as revoicing or restating others' responses. The interventions were designed to improve upon past instructional practices based upon research recommendations. With appropriate collaboration interventions, collaborative robotics projects have the potential to benefit students learning attitudes and achievement.

Learning Motivation in Robotics

The hands-on nature and materials in the elementary engineering lab seem to provide sufficient motivation to some students (Petre & Price, 2004). However, researchers continually turn to instructional methods that involve a problem, meaningful units, and are cross-curricular in order to motivate and engage other students (Blumenfeld et al., 1991). Increases in student motivation are associated with constructivist and problem-based learning (Barak & Zadok, 2007; Bers, 2010; Eguchi, 2012, Papert, 1993; Somyürek, 2014). Moreover, integrated robotics projects combine educational tools with experiential learning to promote an increase in student learning motivation for STEM subjects (Blanchard at al., 2010; Mohr-Schroeder et al., 2014; Petre & Price, 2004; Somyürek, 2014; Ucgul & Cagiltay, 2014). The role of facilitator becomes critical in robotics projects to help sustain student motivation and promote the desired higher level learning (Blumenfeld et al., 1991). When students have the necessary collaborative provisions in order to create a supportive classroom environment during robotics projects, the results can positively impact student learning motivation (Yuen et al., 2014). Student motivation contributes to successfully learning and retaining the content (Mohr-Schroeder et al., 2014). The use of robotics in the classroom has the potential to motivate students to learn, however, it must be noted that the introduction of robotics alone does not guarantee positive student impacts (Eguchi, 2012). Indeed, the teacher must shift to a new role and implement appropriate instructional practices in order to support the learning process, collaboration, and to promote the benefits of student learning and motivation (Blumenfeld et al., 1991; Yuen et al., 2014).

With teachers taking on new roles as facilitators in the shifting learning environment, students are also asked to take on new roles as collaborators. The new roles allow students to take a more active role in their own knowledge development when participating in constructivist and problem-based learning, which increases motivation (Barker & Ansorge, 2007; Blanchard et al., 2010; Chambers et al., 2007; Hwang & Wu, 2014; Liu et al., 2010; Papert, 1993). Not only do students have the opportunity to be active learners, they also have the potential to positively impact student learning and motivation through peer collaboration (Blumenfeld et al., 1991; Eguchi, 2012; Robinson, 2005). Small group settings for robotics necessitates social and peer interaction. With scaffolding and direction for students on successful collaboration, robotics has the potential to promote quality social interactions which support successful collaboration and increase motivation (Denis & Hubert, 2001; Hwang & Wu, 2014). If the nature of robotics is not motivating enough for students, the collaborative nature of robotics projects, constructivist learning, and problem-based learning may offer social interactions that support and maintain student motivation (Slangen et al., 2010; Yuen et al., 2014). The collaborative robotics projects in the elementary engineering lab integrate characteristics of constructivist and problem-based learning that have been shown to motivate student learning and engage students in the learning process.

Collaborative Problem Solving in Robotics

While there are opportunities in the elementary engineering lab to practice problem solving at the individual level, the fourth and fifth grade robotics projects rely heavily on collaborative problem solving. Collaborative problem solving is defined by Mills et al. (2013) as a process where peers construct new knowledge together that neither of them had prior knowledge of before working together. By practicing collaborative problem solving in a real world application with peer and teacher support, students may improve their problem solving skills and possibly promote transfer across content areas, especially if those content areas are integrated into the activities (Jordan & McDaniel, 2014; Mills et al., 2014; Petre & Price, 2004). Research suggests that problem solving engages students in the learning process, as opposed to more passive learning, and is essential for developing real world skills (Eguchi, 2012; Jordan & McDaniel, 2014; Mills et al., 2013; Papert, 1993; Somyürek, 2014). Utilizing the design process for identifying a problem and developing a robotic solution can increase students' use of critical thinking and problem solving skills (Barak & Zadok, 2007; Barker & Ansorge, 2007; Castledine & Chalmers, 1993; Jordan & McDaniel, 2014). In addition, researchers argue that acquiring problem solving and critical thinking skills is essential for student futures (Castledine & Chalmers, 1993). Nelson (2012) emphasized there is more than content preparation needed to implement robotics projects, some of which are less tangible. If these less tangible preparations are addressed through the implementation of effective strategies, additional student benefits can be achieved with skills-transfer (Nelson, 2012).

Understanding the characteristics of collaborative problem solving will assist in determining what scaffolds would best support student learning. Since collaborative problem solving is a form of problem solving requiring peer interactions (Mills et al., 2013) students need to ask questions, gather information, and reflect on what they have learned in order to solve a problem (Somyürek, 2014). Though the process may seem simple enough, it requires complex skills (Somyürek, 2014). In fact, problem solving is a complex phenomenon that utilizes both conscious and unconscious processes as well as combinations of explicit knowledge and intuition (Barak & Zadok, 2007). However, the process can be simplified for students by breaking problem solving into a series of steps (Mills et al., 2013). Another potential support for collaborative problem solving is the use of language to promote the collaboration and the development of newly co-constructed knowledge (Mills et al., 2013). The potential benefits for collaborative robotics projects to facilitate teamwork, problem solving, and critical thinking may be supported through language scaffolds (Hwang & Wu, 2014; Mills et al., 2013). While collaborative problem solving may prove to be a challenge for students because of the complexities, experiences with collaborative problem solving allow students to develop group solutions to meet the common group goal (Denis & Hubert, 2001; Jordan & McDaniel, 2014; Mills et al., 2013). However, the uncertainties of collaborative problem solving may also create barriers to students' development of solutions (Jordan & McDaniel, 2014). Jordan and McDaniel (2014) determine that teacher and peer support is critical for managing the uncertainties of collaborative problem solving. While it may be difficult to support successful collaborative problem solving, the student benefits are worth the teacher's effort. Students' ability to reflect on and relate problem solving strategies in relation to real world contexts could boost confidence levels in the subject area (Castledine & Chalmers, 1993).

The collaborative problem solving and the group work required with robotics projects may also make it more difficult to identify individual student progress. Teachers must closely monitor individual students, their understanding, and their performance in order to support successful projects (Eguchi, 2012). Papert (1993) identifies ways in which to guide student thinking, but cautions that problem solving cannot be as simple as memorizing a procedure, such as a math algorithm, because the variety of problems are always changing. In addition, Papert (1993) reminds us that students do not have to give up old methods to learn new ones. Furthermore, structured thinking is powerful thinking and is not a skill that all students develop when left to construct their own knowledge (Papert, 1993). The role of the teacher, as facilitator, then, is to develop the proper balance as well as organize the instructional plan to support the learning process.

Science Process Skills in Robotics

While instruction in the elementary engineering lab focuses on engineering, the use of cross-curricular instruction is also a priority in order to develop connections for the students between the general classroom and the engineering lab. Nelson (2012) identified the scientific method and engineering as primary rationales for STEM education and robotics integration. Fortunately, integration of science skills fits easily within engineering and robotics instruction (Eguchi, 2012; Papert, 1993). For instance, robotics helps students master various concept areas, depending upon how the robotic instruction is developed. As a result, multiple student benefits are possible by using robotics as cross-curricular activities (Eguchi, 2012). The structure of collaborative robotics projects and robotic materials provide an opportunity to focus student learning on engineering (Bers, 2010; Jordan & McDaniel, 2014; Petre & Price, 2004; Ringwood et al., 2005; Yuen et al., 2014). With the cross-curricular potential of robotics, the use of a collaborative robotics project can easily combine science and engineering in addition to creating connections between the elementary engineering lab and the general classroom. Research identified three main skills developed through the use of robotics; thinking skills, science process skills/problem-solving skills, and social interaction/teamwork skills (Benitti, 2012; Hwang & Wu, 2014; Mills et al., 2013; Ringwood et al., 2005; Slangen et al., 2010). These skills are applicable and valuable for engineering, science, and the general classroom setting. In addition to the identified three main skills, Benitti (2012) noted robotics activities required the use of thinking skills and scientific reasoning. Furthermore, Sullivan (2008) maintained that an appropriate open-ended instructional approach, in conjunction with the use of robotics promotes the use of thinking and science process skills, as well as increased systems understanding.

Science requires students to use language as a component of critical thinking and is necessary in order to understand and identify solutions for problems (Mills et al., 2013). Sullivan (2008) suggests that the process of debugging a program is an ideal format for teaching science process skills. Students generate hypothesis about what would work in the program, test it, and receive immediate feedback. The feedback starts as an iterative cycle of observation, hypothesis generation, testing of the hypothesis, and evaluation of the solution (Sullivan, 2008). This is not only an appropriate format for teaching science process skills, but also emphasizes the real-world process scientists engage, while offering a different exposure to science, since typical classroom lessons do not have the iterative feedback loops (Sullivan, 2008). Sullivan (2008) makes clear connections between the scientific process and the engineering design process by arguing that students must control variables and change only one variable at a time. This is key in the use of the scientific method and science process skills. A study by Somyürek (2014) indicates that during robotics instruction, students learn by designing and programming robots to solve problems. They use scientific skills such as making predictions, generating a hypothesis, conducting experiments or tests, and presenting their results. Robotics provides a hands-on method for teaching critical thinking, science process skills, and support for learning abstract concepts (Eguchi, 2012; Papert, 1993; Slangen et al., 2010; Sullivan, 2008). Though the learning objectives for the collaborative robotics project may not connect specifically with science standards, implementation scaffolds and problem-based learning could assist the students in achieving similar beneficial learning outcomes.

Group Role Assignment in Robotics

No matter the learning objectives of robotics activities, students are most likely working in groups. How does the teacher make sure that all the students in the group are developing the same understanding or meeting the desired learning objectives? Perhaps supports can be established that encourage students to participate equally in the various aspects of the robotics project. Yuen et al. (2014) studied collaborative robotics projects and group tasks, interactions, and dynamics. The study determined that groups need structure. Furthermore, the structure should enable group members to coordinate and complement each other rather than inhibit the completion of the established goal (Yuen et al., 2014). Additional studies have shown that students learn best from their peers when there is a clear division and sharing of responsibilities (Eguchi, 2012; Mills et al., 2013). Yuen et al. (2014) suggest that group roles be determined by individual strengths and weaknesses. However, a classroom educator's goal is to develop strengths where none may exist and allow all students to exposure to a variety of tasks. Lack of exposure may have limited the development of strength or interest. Moreover, Hwang and Wu (2014) defined collaboration as a group who were mutually engaged in solving problems or completing a task. Assigning group roles in this study was an attempt to promote mutual engagement and provide an outline for how that engagement would function with interlocking roles.

The roles, for the purpose of this study, were not assigned based on strengths but rather for the purpose of exposure and achievement of the learning objectives Students also had the opportunity to work in their areas of strength and to improve areas of weakness. In order to guide students in equal participation and work on various aspects of the robotics projects, assigned group roles were developed. The assigned group roles did not take into account Yuen et al.'s (2014) recommendation to be aware of the group members' strengths and weaknesses. Even in Yuen et al.'s (2014) study, after discussions of assigning roles based upon participant strengths, group roles were reassigned during the study to allow all group members an equal opportunity to work on the various aspects of the robotics project. The assigned roles provide structure and procedures that guide individual group member's actions, group participation, while encouraging all group members to be active participants (Yuen et al., 2014). The challenge of keeping all students actively engaged in their groups may be a greater issue depending upon the size of the group. When examining educational robotics camps group size was relevant, for as group size increased the number of students with strengths in a particular area increased as well; however, materials were limited, which may prove an imbalance of the group members with the available materials (Ucgul & Cagiltay, 2014). If groups are too large, students may have difficulty remaining active participants (Eguchi, 2012; Ucgul & Cagiltay, 2014).

Providing supports and scaffolds, such as assigned group roles, has the potential to alleviate some of the challenges of collaborative group projects, such as actively participating and equal share of the work load. When examining the use of educational robotics, it is important that group roles be assigned to balance quiet group members with more dominant group members (Somyürek, 2014). It is also important for all group members to have a visible contribution to the completion of the robotics task (Somyürek, 2014). Ucgul and Cagiltay (2014) noted that the main cause of problems within groups occurred when members felt as though they had to do a larger share of the work or were not given the opportunity to build and share in the work. While these situations may occur no matter the established group structure, the assigned group roles may alleviate such occurrences and provide a method for the group members to address the issue via the assigned group roles. Additionally, assigning group roles encourages students to work cooperatively and engage in task sharing or equal divisions of labor (Ucgul & Cagiltay, 2014).

Research indicates assigned group roles have the potential to counter difficulties within collaborative student groups and may actually promote collaboration and cooperation. While there are recommendations for how to structure group roles, there is little information on specific implementation or steps to take in the classroom setting.

The educational setting may actually have different goals for group members than a team setting. However, implementing potential roles or jobs, such as builder, programmer, or tester, with a job description may manage questions of what each of the group members should be doing during class and rotation of the jobs can provide students with a variety of experiences (Yuen et al., 2014). With such job descriptions, students may also be able to be address any questions or concerns within the group, rather than requiring the teacher as a mediator, thereby further supporting the collaborative nature of the group and promoting the common goal or purpose of the group.

Classroom Discussions in Robotics

Typical classroom discussions in the elementary engineering lab consist of explaining what needs to be accomplished during the class, giving directions, and asking if there are any questions. Rather than being a true discussion, it is simply a method for imparting instructions and checking for clarification. There is significant room to improve upon this strategy for the purposes of supporting collaboration. Yuen et al. (2014) highlight discussion as an important communication aspect for collaborative projects and define true collaboration as active participation and dialogue between all the group members. Discussion within groups assists students in developing a robotic solution (Barak & Zadok, 2007). By engaging in classroom discussions, the teacher can model desired dialogue and discussion strategies for the students to use during their group work (Barak & Zadok, 2007; Mills et al., 2013; Yuen et al., 2014). In fact, discussions can be used in a variety of ways. Mills et al. (2013) use classroom discussions prior to starting each lesson in order to assist students in developing the appropriate robotics vocabulary needed to communicate within the group and develop increasingly complex problem solving skills. Student participants even begin using clarifying questions and directive statements to focus their group members on particular solutions (Mills et al., 2013). The SPIRIT robotics curriculum also begins each lesson by asking questions to promote classroom discussion and the sharing of student ideas (Grandgenett et al., 2012). Mills et al. (2013) use discussions between teacher and students as a check for understanding as well as a method to teach collaboration strategies. In order to support students in collaboration and collaborative projects, developing student discussion skills may benefit collaborative problem solving and assist the teacher in identifying students' understanding of both content and collaboration skills.

Students need to practice and develop discussion skills that support collaboration. Modeling of the vocabulary in the discussion can help students internalize the terms and use a common vocabulary with each other (Hwang & Wu, 2014). In addition, language is integral to student learning and problem solving interaction (Mills et al., 2013), thereby indicating that classroom discussions create benefits, not only by promoting desired group interaction, but also by benefiting student collaborative problem solving and academic achievement. Furthermore, discussion allows students to self-examine and to enhance their cognitive development (Mills et al., 2013). For each new task, Mills et al. (2013) allow groups an opportunity to discuss and formulate a plan to solve the challenge. While these are important topics, the discussions may not be beneficial if all the group members ideas are not shared or valued and if the interaction between the group members takes on a negative characteristic.

Robotics have a positive effect on students' social and collaborative skills (Hwang & Wu, 2014; Mills et al., 2013; Slangen et al., 2010; Ucgul & Cagiltay, 2014).

In fact, social learning may be the most important student benefit of collaborative robotics projects skills (Ucgul & Cagiltay, 2014; Mills et al., 2013; Hwang & Wu, 2014). Hwang and Wu (2014) emphasized that learning to carry out collaborative tasks is critical for the development of students' social interactions. The use of communicative skills such as listening, accepting, and responding, encouraged students to express their own ideas and opinions as well as make constructive comments (Hwang & Wu, 2014). Language also plays an important role in the collaborative problem solving behaviors of students (Mills et al., 2013). Students with the appropriate language skills begin with statements of the problem and used clarifying questions and directive statements to maintain the group's focus on identifying solutions (Mills et al., 2013).

Since effective collaboration is so important, discussion skills should be taught in order to further develop the collaborative nature of the groups and potentially increase student benefits in learning motivation, collaborative problem solving, and science process skills. Yuen et al. (2014) found that when groups had difficulty with the collaborative process, students reverted to group members' ability and experience levels rather than taking turns effectively. Students' whose groups had difficulty collaborating indicated that they had not learned as much nor did they have as positive experiences as students' whose groups collaborated effectively (Yuen et al., 2014). A review of the literature suggests that discussion is paramount to successful collaboration. In order to promote successful collaboration and support student learning in collaborative robotics projects, for the purposes of this study, a classroom discussion intervention is implemented.

Level of Expertise in Robotics

This study was conducted with elementary engineering students of two different experience levels. Students in fourth grade had no prior experience with designing and building a robotic solution. The fifth grade students who had attended the school during fourth grade had previous experience with a similar-styled projects. Although some differentiation was provided in the past in the elementary engineering lab, based upon experience level, it may not have been sufficient to promote student success in collaborative robotics projects. Eguchi (2012) argues that it is very important to provide inexperienced students with supports, and in fact, emphasized the essential teacher's role as facilitator to support inexperienced students. Teachers should provide modeling, guiding, and project planning and assist with the necessary skills and thought processes for students to successfully complete robotics projects (Barak & Zadok, 2007; Eguchi, 2012). While, neither fourth nor fifth grade students had experienced this particular collaborative robotics project, the fifth grade students had more prior knowledge and experiences to draw upon in order to help them successfully complete their robotics projects. The past instructional practices and the design of the study may not provide enough support for the inexperienced students since they are receiving the same interventions as the fifth grade students and no other scaffolds.

The lack of additional supports for inexperienced students may impact potential benefit for the fourth grade students in the study. According to Barak and Zadok (2007) students with varying experience levels tend to approach robotics problems from different perspectives. Inexperienced students may have difficulty in describing problems, which can hamper the success of the group in developing solutions, while experienced students may be able to use collaborative techniques such as being able to re-describe or re-define problems (Barak & Zadok, 2007; Blanchard et al., 2010). If a description of the problem is an issue, robotics vocabulary instruction or modeling may be beneficial to inexperienced students to alleviate possible barriers to problem solving issues. Furthermore, modeling of appropriate discussion could provide support for inexperienced students to overcome any differences in perspectives. Another concern with the differences in experience levels is that novices may rely more on trial and error where experts use domain-specific strategies (Barak & Zadok, 2007; Papert, 1993). Blanchard et al. (2010) demonstrate that experienced students still may use trial and error, but may also use it more efficiently base upon their prior knowledge. Experts are able to develop "chunks" of specialized knowledge that are transferable while novices tend to memorize small disconnected facts (Barak & Zadok, 2007). The expert use of knowledge may allow for shortcuts or efficiency in problem solving rather than having to follow a specific method from start to finish (Barak & Zadok, 2007; Blanchard et al., 2010). It is recommended that students within a group be at similar levels of expertise so that one group member is not an expert, and thereby supporting the co-construction of knowledge rather than expert to novice transmission of information, as in a teacher-directed situation (Barak & Zadok, 2007; Mills et al., 2013). The Mills et al. (2013) study also demonstrates that novices with no prior knowledge of building or programming a robot continue to improve their speed of problem solving. Can this increase in speed or success of problem solving be maintained at the experienced level?

Barak and Zadok's (2007) comparison between expert and novice robotics problem solvers highlights the importance of experience level in effective design and problem solving. While this is a factor that is out of the teacher’s control, it is an important factor to consider for structure of the instruction. Perhaps novice students require more support and scaffolds to develop a successful collaborative process and support the growth of all students in collaborative problem solving, learning motivation, and scientific process skills within the robotics project.

CHAPTER THREE: METHOD

Research Design

A quasi-experimental method was used to examine the research questions within the natural classroom setting. A true experimental method could not be used since students were assigned to groups based upon their general classroom teacher and their grade levels, rather than a random selection of the entire potential participant pool. It was not possible to introduce all three interventions in a single classroom because the interventions would potentially impact each other within that small setting. Each intervention was, instead, assigned to one classroom from each grade level. One fourth and fifth grade class received intervention through structured classroom discussions. Another fourth and fifth grade class received assigned group roles as the intervention. The last set of fourth and fifth grade classes received no interventions and experienced the previous instructional practices as it had been conducted in the elementary engineering lab in the past. However, the randomization of the student groups in each classroom provided an opportunity to evaluate groups with varying abilities, interests, and skills.

Data collection consisted of quantitative data. Independent variables included the interventions implemented and grade level or robotic experience level. Dependent variables included measures of student learning motivation, collaborative problem solving, and science process skills. Quantitative data was collected using the Fowler Science Process Skills Assessment and the Robotics Expo 2012 [Pre CEENbot] -

Adapted 2015 Student Survey. Pre and post measures were given for both quantitative measurements.

Figure 1 illustrates the research design for this study. Each of the experience levels have groupings for the three levels of intervention. This creates a total of six groups of participants, Novice/Classroom Discussion, Novice/Assigned Group Roles, Novice/Previous Instructional Practices, Experienced/Classroom Discussion, Experienced/Assigned Group Roles, and Experienced/Previous Instructional Practices.

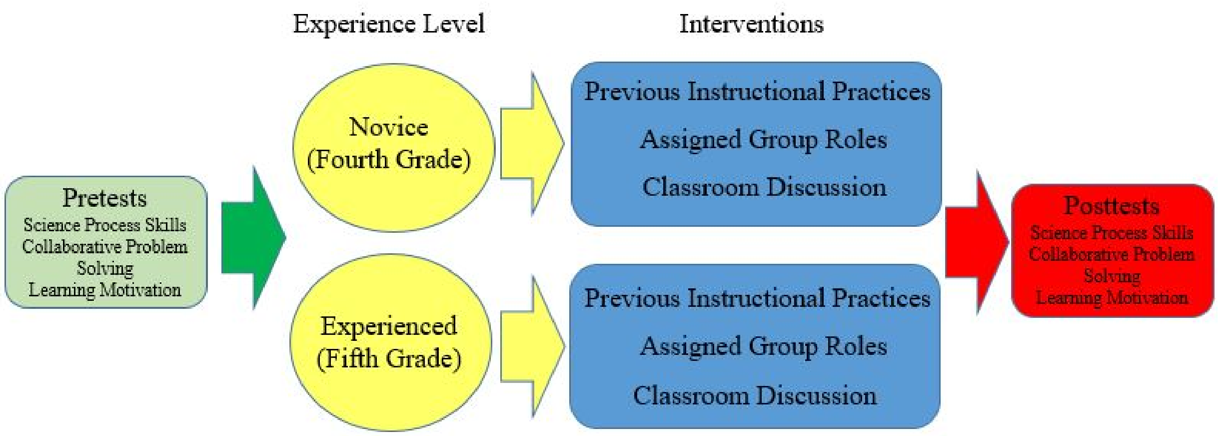


Figure 1. **Research Design**

Research Context

Currently, students working in the elementary engineering lab experience difficulty with successful group interactions and developing appropriate robotic solutions to real-world problems. Last academic year (2014-2015), fifth grade students participated in a robotics project to develop a Mars Rover for detecting life on Mars. They were allowed to use basic instructions for the design and add original elements, or they could develop an entirely original design. Nelson (2012) identified formulaic instructions as a pitfall for robotics instruction. However, the use of instructions allowed students with less confidence to begin a project and then create an original aspect of the working model, or modification. When some students discovered issues with the design, they took the build completely apart to start over, even with limited time, rather than identifying the problem in the design and correcting the issue. Other students could identify the problem with their design but did not know how to undertake the process to change the design even after identifying the problem. Students had difficulty identifying issues with the programming of the robotic solution as well. While constructivist learning emphasizes students developing their learning through hands-on experience, proper scaffolding and facilitation is also necessary to assist the students in developing the collaboration and problem solving skills needed for robotics success. The elementary engineering robotics projects are collaborative due to the limited number of robotics kits and recommended instructional practices. Observing the groups in the past, some groups have better experiences than others. In the present study, developing collaborative supports for the required group work in robotics projects may improve the benefits from robotic projects for all students.

Participants

The target group consists of fourth and fifth grade students at Galileo STEM Academy within the elementary engineering lab. The 179 study participants included students who participate in the district gifted and talented program, special education, and general school population. There are no academic requirements for entrance into the school, only a lottery process. The school is a suburban public school of choice that requires an application to a lottery and successful drawing to be admitted. With a waiting list for kindergarten through fifth grade, not all student applicants are admitted through the lottery process. Due to the nature of the school, there is low turnover rate between the elementary grade levels. Each classroom may have, at most, five new students added each year. The lack of fluctuation in students maintains a consistent student population for the majority of the first through fifth grades.

The students at Galileo STEM Academy currently work with the LEGO Mindstorms robotics in third through fifth grade. The fourth and fifth grade levels consist of three classrooms for a total of six classes. Of the 91 fourth grade students and 88 fifth grade students the study started with, 42% were female and 58% were male. The students attend engineering for a one-hour class each week. The 179 fourth and fifth grade students, range in age from 8 to 11, experience a variety of engineering projects, including 3D printing, building with Fischertechnik, and designing and programming robotic solutions using the LEGO Mindstorms. The targeted fourth and fifth grade groups have one or two years of robotics experience using the LEGO Mindstorms, dependent upon their grade level. However, fourth grade students have not experienced the robotics project in the elementary engineering lab, which requires a group of students to design, build, and program a robotic solution from a kit. Therefore, the fourth grade students were identified as Novice in regards to completing a robotics project. Fifth grade students who attended the school during the previous year have completed a similar project, which required the design, building, and programming of an art robot that could create designs by using a repeating pattern. While this project had different criteria, students still had to develop the skills to design, build, and program the robotic solution from a kit, establishing them as Experienced. Five fifth grade students were new to the school this year and did not have previous experience with robotics projects. Therefore, those five students were identified as Novice.

Student groups within each classroom were established with random assignments, based on an existing strategy used in the class of students, choosing a number from a deck of cards and sitting at the corresponding table. The majority of the student groups consisted of four students with some groups of three as indicated in Figure 2. The number of groups with three students totals 13 groups overall. In December 2015, toward the end of the study, new students were added to existing groups of three in two of the fifth grade classrooms. The number of groups with four student members totaled 33 groups at the beginning of the study and 35 upon completion of the study. Group size is determined by class size, and available materials. Enough LEGO Mindstorms robotics kits were secured for the purposes of the study in order to ensure no groups exceeded four student members.

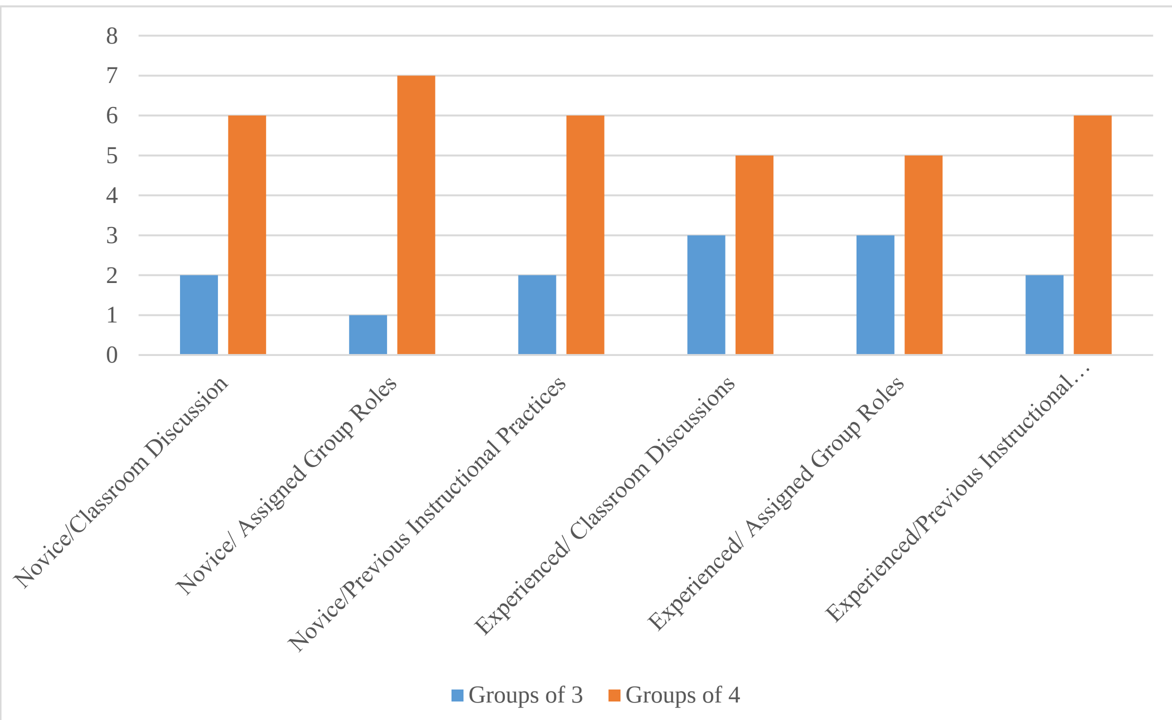


Figure 2. **Group Sizes.** The chart identifies the number of groups of three and four students based upon the experience levels and the intervention.

Each of the three intervention conditions started with sizes of approximately 60 students as seen in Table 1. Furthermore, each of the sub conditions divided by experience level had approximately 30 students.

Table 1. Students in Intervention Conditions by Experience Level

Intervention	Fourth Grade/Novice	Fifth Grade/Experienced	Total
Previous Instructional Practices	30	30	60
Assigned Group Roles	31	29	60
Classroom Discussion	30	29	59
Total	91	88	179

All six intervention conditions, or all six classes, used Engineering Notebooks with the specific instructions for the notebooks in writing for the Assigned Group Roles. The addition of the notebook was planned for the 2015-2016 instructional year and was not an aspect of any collaborative intervention. The Engineering Notebook was introduced to promote student recording of their thoughts, co-construction of knowledge, discussion, and reflection during elementary engineering, and was not specifically used for the purposes of the present study.

General Method of Instruction

The students in fourth and fifth grade use a variety of hands-on materials to explore engineering concepts. Students attend elementary engineering once a week for an hour as a special class, much like music and P.E. Various materials and instructional methods are used for fourth and fifth grade when building models from LEGO Technic or Fischertechnik. The students typically build models from instructions, either individually or with a partner. At times, a more open-ended problem-based approach is used where students are given criteria for the build with no instructions to follow. For example, fifth grade students are asked to build a vehicle that can climb inclines. When testing the design, the incline is adjusted to see how steep of an incline the vehicle can successfully navigate. Students use prior knowledge from instruction guided builds to design and build a working vehicle. Open-ended challenges sometimes use groups of three to four students, or partners, depending upon the complexity of the project. Rarely do students complete open-ended challenges individually. Projects in elementary engineering requiring the students work in groups of three to four students do not typically extend beyond three to four classes and only occur, at most, two to three times an instructional period. The robotics project is the only project that requires students to work within the same group for extended periods of three to four months.

LEGO Mindstorms robotics instruction begins in third grade with students working with a partner to learn basic programming skills using the NXT tutorials to develop a variety of skills. Students start with programming the robot to move forward. A distance challenge follows the lessons on programming the robot to move forward. Next the students learn the two different types of turns. They work through the tutorials of the Mindstorms software and then are given a challenge of completing a mat that was created with both point and curve turns within the pattern. Students in fourth and fifth grade continue to work on their programming skills with a partner, advancing to the sensors and more complex programming. The progression from basic programming to complex designs and builds follows Ucgul and Cagiltay’s (2014) recommendation that content be organized from simple to complex. The instructional sequence provides the necessary experiences and prior knowledge for students to take on the more complex collaborative robotics projects.

The robotics projects take place only in fourth and fifth grade and require students to design, build, and program a robotics solution with the criteria for the project changing each year. Collaborative robotics projects are designed to reinforce and assist with learning in the general classroom by targeting science, math, language, and engineering standards. The use of technology, through the robots, promotes the cross-curricular aspect of STEM in real world practices. The use of the Engineering Notebooks and the presentation of their group solution to their peers reinforces language standards, promotes student reflection, and co-construction of knowledge in group projects. The process of identifying problems and developing solutions promotes science process skills and engineering practices. The collaborative robotics project requires students to use what they have learned about robots and fosters the development of new knowledge in order to design, build, and program an original solution to a problem they identify based upon the given criteria. Students have the option of using instructions to design the base of their robotic solutions, but are required to add an original working part or modifications. Ucgul and Cagiltay (2014) found that students had the most difficulty with mechanical building and programming; however, the use of instructions alleviated some of these issues. Allowing groups to begin their design with the use of instructions can assist students in managing the project within the given time constraints.

This academic year (2015-2016) students were asked to identify problems at school that could be solved with a robotic solution. The class sizes ranged from twenty-nine to thirty-one students at the beginning of the study and thirty to thirty-one students at the end. Eight robotics kits were available for each class which allowed for an entire grade level of classes to complete a project at the same time with group sizes of three to four students. The majority of the groups have four students with the minority of groups being the recommended size of three students. Students were required, as in past projects, to brainstorm problems and potential solutions prior to receiving their robotics kits. In the past, in order to support the group work, students have been given criteria for the project and asked to ensure everyone is included in developing the design, building the robot, and programming the robot. Student participants completed their collaborative robotics project over sixteen weeks for one hour each week. The project was extended from the usual twelve week, or trimester, project from past instructional years for the purposes of the study. Students were reminded each class of the time limitations because it has been difficult in the past for students to understand the limited amount of time available when a project extends for four months. Therefore, time reminders were given in terms of hours rather than days, or weeks, to provide a more realistic understanding of the actual available time. Robotics projects in the past have been limited to a trimester in order to share kits between fourth and fifth grade. The additional robotics kits for the study allowed both grade levels to participate at the same time and provided an opportunity to extend the traditional trimester time frame and allow both grade levels more time to experience designing, building, and programming a robotic solution.

All intervention conditions of students experienced the same robotics teaching sequence as seen in Table 2. Variations were made in the instructional practices, based upon the intervention condition, in order to target the specific collaborative strategies. All the intervention conditions were instructed each class to share the work, make sure everyone had a turn building and programming the robot, and that each student should include notes each class in their Engineering Notebooks. No specific modifications or changes were made based upon the experience level of the students.

Table 2. Collaborative Robotics Teaching Sequence

Lesson	Activities
1	Complete pretest, introduce challenge, students brainstorm problems to solve, and identify possible solutions to the problem the group chooses
2	Groups receive robotics kits, inventory kits, continue developing problem and solution
3	Begin designing and building robotic solution
4	Continue designing and building robotic solution
5	Continue designing and building robotic solution
6	Begin programming and testing
7	Continue testing and improving program and design
8	Continue testing and improving program and design
9	Continue testing and improving program and design, develop student generated evaluation rubrics
10	Continue testing and improving program and design, finalize student generated evaluation rubrics
11	Continue testing and improving program and design, begin preparing presentation
12	Continue testing and improving program and design, continue preparing presentation
13	Continue testing and improving program and design, finalize presentation
14	Finalize and practice project demonstration and presentation
15	Present and demonstrate robotic solution
16	Wrap-up, students evaluate themselves and their fellow group members, complete posttests, inventory robotics kits.

In addition to following the same basic instructional outline for the collaborative robotics project, all three intervention conditions, Previous Instructional Practices, Assigned Group Roles, and Classroom Discussion, were reminded and encouraged to collect their own notes in their Engineering Notebooks, but all group members in Assigned Group Roles had notes as part of the jobs under their assigned roles. The data manager was specifically required to take detailed notes for the group each class. The students used a notebook for the first time this year (2015-2016) in the elementary engineering classroom. The Engineering Notebook was introduced briefly prior to the start of the study through the use of other activities that encourage observation and recording of data. However, the students only used the Engineering Notebook for two classes before beginning the collaborative robotics projects. Reminders were needed for students to utilize the tool and reinforce the teacher expectations but were not always heeded. The Engineering Notebook provided an opportunity for students to record individually constructed and co-constructed ideas and observations. Not all students took advantage of the opportunity. The students also had the opportunity to reflect upon various aspects of robotics in the Engineering Notebook. Students created and maintained their Table of Contents based upon a teacher-recommended guideline visible each class on the board at the front of the room. Guidelines for labeling each page of the notebook with a heading that included the date was also on the board each day. Students were informed that the Engineering Notebook would be reviewed by the teacher as required when journals are used within the classroom. The Engineering Notebook was not used as a grading component of the collaborative robotics project or the elementary engineering classroom, but rather as an opportunity for the teacher to verify the appropriate tasks were completed in all three of the interventions, especially the Assigned Group Roles. The notebook was not a component of the data collection or analysis.

Interventions

Classroom Discussion

The interventions are designed to create a safe and supportive collaborative environment for all the students. The first collaborative support used classroom discussions including establishing expectations and developing a safe environment for sharing ideas. Additional supports were included throughout the project to reinforce the expectations and promote effective discussions both within the group and as a whole class (Lesson Plans, Appendix A). Restating someone else's thoughts, increasing wait time, partner talk, and encouraging many contributors were strategies used for the intervention, modeled after the classroom strategies in Classroom Discussions Using Math Talk to Help Children Learn (Chapin, O'Connor, & Canavan Anderson, 2012). Whole class discussions provided the teacher time to model strategies and assist students in developing the strategies, with redirection if necessary. The teacher also had the opportunity to monitor group discussions by visiting groups during the course of the class time. Checking in with each group allowed the teacher to assess how the group discussions were progressing and provided opportunities for additional modeling and redirecting within a small group setting rather than the whole class (Mills et al., 2013). The goal was to model and promote collaborative discussion techniques and assist students in implementing these strategies in their collaborative robotics groups.

Specific implementation guidelines and strategies, as developed by Chapin et al. (2012), provide classroom examples for the teacher to use when leading classroom discussions about mathematics. The strategies are applicable to the problem solving in engineering and science. Five principles were established for productive talk, according by Chapin et al. (2012): 1) establishing and maintaining a respectful, supportive environment, 2) focusing talk on mathematics, 3) providing for equitable participation in classroom talk, 4) explaining your expectations about new forms of talk, and 5) trying only one challenging new strategy at a time. In order to develop the first principle, of a safe and supportive classroom environment, it was important to emphasize to the class that all students have the right to be heard and their ideas listened to with respect (Chapin et al., 2012). This was reinforced during large classroom discussions and during the check in time with each group, along with principle two. To assist with on-task behavior, principle two was effective in reminding students that the focus of group discussion should be relevant to the project. Each class, students were reminded of principle three, with equitable participation in not only the group discussions, but also during the building and programming of the robot. Chapin et al.'s (2012) principle four was used when the teacher introduced a strategy to explain the expected behaviors. Students do not innately develop discussion skills and need direct instruction on the expectations and reflection upon the modeling being done by the teacher. For example, when modeling the restating of a student's response, the teacher would confirm with the student whether the restatement was correct. Then the teacher asked the class "Why did I check if I had restated it correctly?" This technique promoted the students understanding of how this strategy helped to clarify understanding and develop a consensus of understanding. Principle five is an important note for teachers. When trying a new strategy that may be difficult to develop, introduce only one such strategy at a time. This allows time to develop the procedures for the strategy with the students before introducing a new strategy.

Strategies from Chapin et al. (2012) were used, with adaptations, to meet the needs of the project, classroom, and the time constraints. Chapin et al. (2012) identify revoicing and wait time as tools most used by teachers. Both strategies were appropriate for students in collaborative groups to promote development of a common understanding and equitable contribution for all the group members. When having whole class discussions, the teacher reinforced that other students should be silent and listen to the speaker at the time, and encouraged students to speak in a voice that could be heard by all the students, not just those nearest them. The teacher promoted the asking of questions, respectful tones, and discussions. At times, modeling an inappropriate way to respond was a good example for students who may not be aware of how a particular tone of voice or phrasing of words can change a response from respectful to disrespectful. Asking students to restate the objective for the day also provided additional practice for revoicing. Multiple student contributions were encouraged by the teacher while the class was sharing successes and challenges. If a group shared a challenge, the teacher asked for possible solutions from other groups prior to offering suggestions. The teacher reminded each group to use respectful discourse and stay focused on the content. Consistent modeling and specific time for classroom discussion provided scaffolding and support for the classroom discussion intervention.

During the past instructional years in the elementary engineering class, there had been little time to implement quality classroom discussion. Therefore, the implementation of classroom discussions require setting aside specific times at the start, middle, and end of class to focus on the intervention. The discussion at the beginning of the class involved students revisiting what the project required and any issues they may have had during the last class that remained unresolved. The discussion during the middle of the class, was an opportunity to check-in and seek assistance in resolving issues, as well as share in successes. The end of class discussion was reserved, as Eguchi (2012) recommended, to share and discuss progress, and to provide a learning opportunity for students and teachers. Students were able to ask questions while they were fresh and provide insights for the teacher as to project progression and instructional supports needed. Making time for sharing and discussion was key for modeling and teaching collaborative skills. The classroom discussions assisted in modeling not only collaborative skills but collaborative problem solving and science process skills. Classroom discussions were designed to promote social skills and student achievement of learning objectives.

Assigned Group Roles

The second intervention was assigning group roles within the project that rotated throughout the course of the project, giving all the group members equal opportunity to develop a variety of skills. The roles consisted of a time manager, materials manager, project manager, and data manager (Appendix B). The time manager assisted the group in monitoring the time they had available in comparison with the tasks to be accomplished for the class time. The materials manager was responsible for gathering and maintaining the materials needed for the project, the robotics kit and other miscellaneous items. The project manager was responsible for the big picture of the project and identifying tasks that needed to be accomplished for the final completion of the project. The data manager recorded any data and notes pertaining to the project. The assigned roles with specific jobs, in addition to the scheduled rotations, were designed to promote a process for the equal distribution of work and the opportunity for all students to develop the skills from all the roles.

The roles were developed after reviewing various robotics group roles and recommendations for use of group roles in collaborative robotics projects. Many of the suggested roles did not meet the needs of the elementary engineering classroom setting, but instead were intended more for use with competitive robotics teams, summer camps, or to develop specialized skills. In order to promote roles where all the group members had equal importance and shared the work, each group role included the term, manager. Furthermore, equal distribution of the design research, designing the robot, building the robot, programming the robot, and recording notes in the Engineering Notebook were emphasized, by being listed as common tasks for all four assigned group roles. The remaining tasks for the four assigned group roles required interaction with each other and were not jobs that could be completed in isolation from the group if performed correctly, again promoting the collaborative structure of the group.

The group roles were assigned the first time the groups met. Following the first class and introduction of the assigned group roles, students rotated methodically through the roles going to the role below their previous role on their Assigned Group Role sheet (Appendix B) during the next class. If a student was absent, they missed their turn with the role they would have performed and the tasks from the missing role that were unique to that role were divided up between the group members in attendance. If the group was only a group of three, each week the tasks for the missing role, that were unique to that role, would be divided between the group members. When groups had only two students present due to absences, the same process would take place for the two missing roles. Introduction of the assigned group roles included drawing attention to the similarities and differences between the roles and developing expectations for students' performance of their roles. Since students were rotating each class, once a week, reviewing the tasks and the expectations for the roles for the first four classes was important in order to assist the students in performing their roles correctly. At the beginning of each class, the teacher could assess student knowledge of their role for the day by asking all the Time Managers to raise their hands and so forth through all the jobs. When groups were dividing up a missing role, multiple or all group members may have their hands raised for that role. Reinforcement of expectations and tasks continued as the teacher monitored and checked in with each of the groups during class time. While some groups adopted the Assigned Group Roles and diligently followed the roles and responsibilities, other groups needed frequent reminders during class to follow their roles for that day. At the end of class, the teacher asked students to review their role for next week so they were prepared to perform the tasks for next class, thus providing an additional opportunity to reinforce expectations for the Assigned Group Roles.

Introduction and reinforcement of the group roles was important in assisting students to meet the teacher's expectations and support potential student benefits to learning motivation, collaborative problem solving, and science process skills. The Assigned Group Roles were designed to promote all group members as active participants and engaged in the common purpose of the collaborative robotics project. Furthermore, the roles were rotated to help develop students' areas of weaknesses and highlight areas of strengths. With the project only lasting a total of 16 lessons, students were able to experience each role at least three times and possibly more depending on group size and student attendance. The quality of the student performance of the Assigned Group Roles was not measured for the study, although students evaluated themselves and their group members with student-generated rubrics for the project. Students had the potential to develop new or emerging skills while having the opportunity to display their existing skill set in various areas. The group roles may have exposed students to areas they would not have previously known they had a talent for, or perhaps, would have avoided due to a lack of interest. Exposing students to various tasks, within the four Assigned Group Roles, models how an effective group may function and encourages students to try new skills, potentially outside of their comfort zone. Assigned group roles may positively benefit student learning motivation by developing new or building upon existing interests, modeling collaborative problem solving by utilizing all members of the group, and promote science process skills through research, design, building, programming, and evaluating the robotic solution.

Previous Instructional Practices

Two classrooms, one fourth and one fifth grade classroom, did not receive the structured Classroom Discussion nor utilize Assigned Group Roles, but rather, continued with the Previous Instructional Practice as outlined initially in General Method of Instruction and the instructional sequence outlined in Table 2. All six intervention conditions followed the same instructional sequence with variations based upon the intervention condition. Additional detailed information can be found in the Lesson Plans in Appendix A. The Lesson Plans demonstrate instruction for the Previous Instructional

Practices condition in the initial section of the lesson with notes specific for the Classroom Discussion and Assigned Group Roles immediately following each lesson.

Students were given the basic criteria for the robotics project, brief reminders and potential tasks that needed to be accomplished for each class, and any questions were addressed. Other than instruction on the collaborative robotics project itself, students did not receive supports for Collaborative Discussion nor were they given Assigned Group Roles. They were reminded to share the work equally, make sure all group members got equal turns building and programming the robot, and given reinforcements for these aspects as needed. Not all students were able to program or build on the robot at the same time. Therefore, these activities rotated through all group members in a method established by each group with the understanding that the time should be divided equally among the group members and everyone should work on the programming or building within each class time. If conflicts or issues arose in a group, they were dealt with on a case-by-case basis, protecting the students from any negative repercussions of the study.

Tools

Fowler Science Process Skills Assessment

Quantitative data was collected from student pre and posttests for scientific process skills using the Fowler Science Process Skills Assessment (Fowler, 1990) (Appendix C). The performance-based test is an open-ended, single question assessment and requires students to write the steps needed to test a scientific question. A different question was used for the pre and posttest. The pretest questions were, "Are earthworms attracted to light? In other words, do earthworms like light? Tell how you would test this question. Be as scientific as you can as you write about your test. Write down the steps you would take to find out if earthworms like light." The posttest questions were, "Are bees attracted to diet cola? In other words do bees like diet cola? Tell how you would test this question. Be as scientific as you can as you write about your test. Write down the steps you would take to find out if bees like diet cola." A scoring sheet was used to measure students' scientific process skills based upon points scored for scientific concepts used in the answer with 1 point for each of the fifteen concepts covered in the student answer and 2 additional points possible for including sub items. A score of 0 on an item indicated no evidence and a score of 3 indicated strong evidence. Final scores could range from 0 to 45 points. However, no scores of 3 were given to any student for any one item. Final scored assessments ranged from 0 to 9 total points. Skills addressed include, identifying the question, predicting outcomes or forming a hypothesis, and repeating test. Student pre and posttest responses for the Fowler Science Process Skills Assessment were analyzed to identify changes in student science process skills and control for prior student knowledge. The validity and the reliability of the Fowler Science Process Skills Assessment as a measure of science process skills has been previously established (Callahan, Hunsaker, Adams, Moore, & Bland, 1995; Fowler, 1990; Mallozzi & Heilbronner, 2013). Furthermore, the intrarater reliability Pearson product-moment correlation coefficient of .89 for the pretest and .91 for the posttest was comparable to other science performance assessments (Callahan et al., 1995).

<u>Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey</u>

Students also completed the Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey (Appendix D) before and after the robotics project to assess student learning motivation and collaborative problem solving. The survey was adapted from the

Robotics Expo 2012 [Pre CEENbot] Survey developed by Grandgenett, Chen, and Timms (2010). It consisted of 38 questions using a 5-point Likert Scale to have participants self-assess for collaborative problem solving and motivation. Students marked their score on a scale from one to five and then their point values were summed up for a total score for each area. Collaborative problem solving had 22 questions at 5 points each question for a possible full score of 110 points. Motivation had 16 questions at 5 points each question for a possible full score of 80 points. Adaptations consisted of removing the demographics and changing the terms team and coach to group and teacher. Student pre and post scores were analyzed to identify changes in motivation and collaborative problem solving while controlling for students' pretest scores. Although the student survey is identified as an attitude instrument, the survey was modeled after Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991) and developed to measure motivation, collaboration, and problem solving strategies (Grandgenett et al., 2010; Nugent, Barker, & Grandgenett, 2010). Nugent et al. (2010) used the survey tool that had a combination of attitudinal and self-efficacy questions to measure student attitudes and motivation using a Likert scale. It was determined that the motivation construct conformed to the recommended fit criteria of Standardized Root Mean Squared Residual (SRMR), Root Mean Square Error of Estimation (RMSEA), and Comparative Fit Index (CFI)" (Nugent et al., 2010, p. 397). Park (2015) also used a student survey with Likert scale to measure motivation based upon student interest, enjoyment, connection to daily life, and importance to the student with twenty questions. Due to the fact that the survey was modeled after a motivation questionnaire and developed to measure motivation, collaboration, and problem solving, the instrument was deemed an appropriate measure for motivation. Furthermore, the questions are consistent with measuring motivation attitudes. The Robotics Expo 2012 [Pre CEENbot] Student Survey has been previously tested for reliability and validity by Grandgenett et al. (2010). The survey had a Cronbach alpha reliability coefficient of .94 (Grandgenett et al., 2010). In the present study, the 22 questions for collaborative problem solving had a Cronbach alpha reliability coefficient of .87. The 16 questions for learning motivation had a Cronbach alpha reliability coefficient of .88.

The self-efficacy aspects of the questions on the Robotics Expo 2012 [Pre CEENbot] Survey, and the relation of how the STEM aspects connect with the student, create an appropriate measure for learning motivation. The adapted Robotics Expo 2012 [Pre CEENbot] Survey met the needs of measuring collaborative problem solving and motivation with one tool, which was important since science process skills were measured with a separate tool. The STEM measure was important in relation to the elementary engineering class for the implementation of the interventions. In addition, the study's measurement of science process skills and the collaborative robotics project, in general, provided STEM connections. The adapted Robotics Expo 2012 [Pre CEENbot] Survey was vetted through the fourth and fifth grade teachers to verify the measure was appropriate for both grade levels in terminology and length.

Data Collection and Analysis

Student data was collected using student names but was then converted to numbers for identification of the participants to preserve anonymity for all the students. Data collection began in mid-September 2015 with the administering of the pretest for the Fowler Science Process Skills Assessment, for measurement of science process skills, and Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey, for assessment of motivation and problem solving. Both were administered during the same class. Both the Fowler Science Process Skills Assessment and the Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey were administered whole class. Students received the pretest prompt and survey instructions. The instructions were read aloud to the whole class, any questions were addressed, and then students began their Fowler Science Process Skills assessment. As students completed and turned in their Fowler Science Process Skills pretest, they were handed the Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey and reminded of the instructions. The instructor also emphasized that the students were evaluating themselves and not their classmates. The pretest and survey took the majority of the hour-long class. Some students had difficulty completing both the assessment and the survey in the class time given. Additional time was given to any students that needed it the following class in order to complete any unfinished surveys or assessments before beginning the brainstorming process with their groups.

In mid-January 2016, the posttest for the Fowler Science Process Skills Assessment and Post Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey. The posttest prompt, which was similar to the pretest, for the Fowler Science Process Skills Assessment and the Post Robotic Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey were administered in identical manner as the pretest. The only difference being, students were given both the posttest and the survey at the same time, rather than having to hand in one to receive the next. Both the Fowler Science Process Skills Assessment and the Post Robotic Expo 2012 [Pre CEENbot] – Adapted 2015

Student Survey were administered during the same class. The hour time limit of the elementary engineering class did not prove to be a difficulty for students as it had for the pretest. Students were able to complete both the posttest and the survey in one hour's time. Whereas some students had difficulty completing both the pretest and survey in an hour, many students were able to complete both measures in half the class time and no one had difficulty getting it completed during the allotted class. The only difficulty encountered in collecting data during the study, arose from student absences. Students who experienced frequent absences missed the opportunity to participate in either the pre or post assessments, and in one case, both.

All methods of data collection consisted of paper and pencil responses from the student participants. Using a digital method of collecting responses had been considered in order to aid data entry, but was not feasible with the number of devices available in the classroom, as compared to class sizes. While written responses created challenges in data collection, with students leaving fields uncompleted, it also provided an opportunity for students to express their feelings and, at times, offered more insight into some of their attitudes and thought processes. For instance, one student even marked themselves higher than the 5-point Likert scale available on their Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey.

Data entry began with student demographics and the pre Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey into a Microsoft Excel spreadsheet. The post Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey was entered at the end of the study. Columns were created for each question on the survey to allow for examination of individual questions if necessary. Pre and post Fowler Science Process

Skills assessments were scored at the end of the study to provide the same scoring for both pre and posttests and reduce variance in scoring. In addition, the tests were scored a second time to provide reliability since a second rater could not be secured to create interrater reliability. The average of the two scores was used to complete the analysis. Columns were created for each of the fifteen criteria on the scoring sheet in addition to a total for the overall score. If needed, analysis could be made of individual criteria. This also allowed for identifying criteria that was commonly met by the students as well as criteria that was frequently overlooked. While not necessary for the purposes of the present study, this practice is beneficial to the classroom educator hoping to identify areas of student strengths and weaknesses.

In this study, interventions were used during instruction for a robotics project to determine what collaboration supports and strategies benefit students in learning motivation, collaborative problem solving, and science process skills. Three intervention conditions were established, Previous Instructional Practices, Assigned Group Roles, and Classroom Discussion. Data analysis investigated the effect of the three interventions in terms of science process skills, student learning motivation, and collaborative problem solving using pre and post scores from the Fowler Science Process Skills Assessment and the Robotic Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey. The purpose of the pre and post data collection was to determine changes that occur as a result of the interventions and the effect of experience level by answering the three main research questions, including their sub questions, “Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students’ pretest scores?”, “Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student collaborative problem solving, controlling for students' pretest scores?", and "Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student science process skills, controlling for students' pretest scores?"

Data analysis was performed in SPSS 21 to determine answers to the main research questions and the sub questions. In order to determine significance at the .05 alpha level and possible interactions, 2x3 ANCOVAs were used for both experience levels and the three interventions while controlling for students' pretest scores. Pretest scores for science process skills, collaborative problem solving, and learning motivation were used as covariates. Tukey HSD followed the results from the ANCOVAs to determine which conditions were significantly different.

CHAPTER FOUR: RESULTS

The data collected for each participant included scores for motivation, collaborative problem solving, and science process skills. Both motivation and collaborative problem solving were self-reported using the Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey. Science process skills were scored using the Fowler Science Process Skills assessment.

Research Question 1

In order to answer Research Question 1 “Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students’ pretest scores?” pre motivation mean scores were used as a covariate and an ANCOVA was applied.

Table 3 indicates the means of pre and post scores for three intervention conditions by experience levels. A full score for motivation would have been 80 points. The post mean motivation scores for Classroom Discussion and Previous Instructional Practices were lower than the pre mean motivation scores. Classroom Discussion had a pre mean score of 66.91 and a post mean score of 65.33. Previous Instructional Practices had a pre mean score of 67.51 and a post mean score of 65.25. Only Assigned Group Roles indicated an increase in post mean scores, which was only a 1 point increase from 68.14 to 69.14. When examining the scores by intervention condition and experience level, both Experienced Classroom Discussion and Previous Instructional Practices had greater than a 4 point decrease. Therefore, only the intervention of Assigned Group roles in the

Experienced level students demonstrated an increase in the post score for motivation according to Table 3.

Table 3. Condition Sizes, Means and Standard Deviations of Motivation Scores

Experience Level	Interventions	N	Pretest		Posttest	
			Mean	SD	Mean	SD
Experienced	Classroom Discussion	25	68.24	6.20	63.56	9.08
	Assigned Group Roles	26	66.65	8.09	66.70	7.22
	Previous Instructional Practices	25	66.84	8.86	61.93	9.89
	Total	76	67.24	7.72	64.06	8.73
Novice	Classroom Discussion	28	65.57	6.06	67.10	6.48
	Assigned Group Roles	27	69.63	7.35	71.57	7.00
	Previous Instructional Practices	23	68.17	8.30	68.56	6.68
	Total	78	67.79	7.24	69.08	6.72
Total	Classroom Discussion	53	66.91	6.13	65.33	7.78
	Assigned Group Roles	53	68.14	7.72	69.14	7.11
	Previous Instructional Practices	48	67.51	8.58	65.25	8.29
	Total	154	67.52	7.48	66.57	7.73

The means of the post survey for the Novice level condition demonstrated over a 1 point increase, while Experienced level demonstrated a decrease of more than 3 points. In addition, the post mean scores for Novice level (69.08) was more than five points higher than Experienced level (64.06). The Novice level Classroom Discussions and Assigned Group Roles for student learning motivation demonstrated increases for post mean scores. Therefore, at the Novice level all three interventions produced a positive impact on student motivation as indicated in Table 3.

In order to answer the three sub questions, “Are there effects of the collaboration interventions on student learning motivation, controlling for students’ pretest scores?”, “Are there effects of prior student experience with collaborative robotics on student learning motivation, controlling for students’ pretest scores?”, “Is there an interaction effect between the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students’ pretest scores?”. In order to test the differences discovered in Table 3 for statistical significance, a 2x3 ANCOVA was applied with the pre motivation scores as covariate. The ANCOVA indicated statistically significant main effects of the interventions for motivation after controlling for students’ pretest scores, $F(2,135) = 5.24$, $p = .006$, $p < .05$, as seen in Table 4. The ANCOVA also indicated statistically significant main effects of the experience level after controlling for students’ pretest scores for motivation, $F(1,135) = 24.97$, $p = .000$, $p < .05$. There was no interaction between intervention and experience level, $F(2, 135) = .77$, $p = .463$, $p > .05$.

Table 4. ANCOVA for Post Total Motivation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3744.17a	6	624.03	13.03	.000
Intercept	1714.65	1	1714.65	35.81	.000
Pre Total Motivation	1704.56	1	1704.56	35.60	.000
Interventions	502.02	2	251.01	5.24	.006
Experience Level	1195.42	1	1195.42	24.97	.000
Interventions * Experience Level	74.15	2	37.07	.77	.463
Error	6464.12	135	47.88		
Total	642431.00	142			
Corrected Total	10208.29	141			

a. R Squared = .367 (Adjusted R Squared = .339)

In examining the motivation levels by intervention and experience level, it can be concluded that there is a statistically significant main effect for the interventions and experience levels. The results of the ANCOVA called for a post hoc analysis for the three interventions using Tukey HSD to determine which conditions were statistically significant. Post hoc results in Table 5 indicated that the mean motivation score for Assigned Group Roles were statistically different in motivation, $p = .011$, $p < .05$ than Classroom Discussion and Previous Instructional Practices, $p = .004$, $p < .05$. Taken together, these results indicate that the use of Assigned Group Roles had an effect on student motivation. Specifically, students in Assigned Group Roles had higher post mean motivation scores when controlling for students' pre motivation scores than the students in Previous Instructional Practices with a mean difference of 4.27 and Classroom Discussion with a mean difference of 3.65. Overall, interventions and experience level produced statistically significant main effects, with Assigned Group Roles demonstrating statistically significant higher post mean scores (69.14) than Classroom Discussions (65.33) and Previous Instructional Practices (65.25), as well as Novice demonstrating statistically significant higher post mean scores (69.08) than Experienced (64.08).

Table 5. Post Hoc Test for Post Total Motivation

(I) Intervention	(J) Intervention	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Classroom Discussion	Assigned Group Roles	-3.65*	1.408	.011	-6.430	-.860
	Previous Instructional Practices	.62	1.445	.668	-2.237	3.477
Assigned Group Roles	Classroom Discussion	3.65*	1.408	.011	.860	6.430
	Previous Instructional Practices	4.27*	1.442	.004	1.414	7.116
Previous Instructional Practices	Classroom Discussion	-.62	1.445	.668	-3.477	2.237
	Assigned Group Roles	-4.27*	1.442	.004	-7.116	-1.414

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Research Question 2

In order to answer Research Question 2 “Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student collaborative problem solving, controlling for students' pretest scores?" pre collaborative problem solving scores were used as a covariate and an ANCOVA was applied.

Table 6 indicates the mean pre and posttest scores for collaborative problem solving. A full score on the collaborative problem solving section was 110 points with 22 questions at 5 points each. Table 6 identifies Classroom Discussion and Assigned Group Roles as having a positive effect with increased post mean scores. Classroom Discussion increased from 89.60 to 90.32 while Assigned Group Roles increased from 92.29 to 93.07. Though these increases are less than 1 point, Previous Instructional Practices demonstrated a decrease of over 2 points from 92.61 to 89.35. Experienced Classroom Discussion, Novice Classroom Discussion, and Novice Assigned Group Roles demonstrated a positive impact on collaborative problem solving. The increase is greatest for Novice Assigned Group Roles. Experienced Assigned Group Roles was less than .1 point of a decrease. Experienced Previous Instructional Practices experienced the largest decrease with 5.68 points difference between the pre and post mean scores for collaborative problem solving.

The post mean scores for Novice level demonstrated a slight increase for collaborative problem solving from 92.81 to 93.32. The post mean scores for the Experienced level indicated a decrease from 90.18 to 88.50. Experienced sub conditions only had positive impact for Classroom Discussion while the Novice sub conditions had positive impact for both Classroom Discussion and Assigned Group Roles.

Table 6. Condition Sizes, Means and Standard Deviations of Collaborative Problem Solving Scores

Experience Level	Interventions	N	Pretest		Posttest	
			Mean	SD	Mean	SD
Experienced	Classroom Discussion	25	89.36	8.78	90.08	8.82
	Assigned Group Roles	26	90.62	9.68	90.54	6.65
	Previous Instructional Practices	27	90.57	9.10	84.89	9.98
	Total	78	90.18	9.19	88.50	8.48
Novice	Classroom Discussion	29	89.83	7.73	90.57	8.49
	Assigned Group Roles	26	93.96	10.51	95.59	8.60
	Previous Instructional Practices	25	94.65	9.44	93.80	8.60
	Total	80	92.81	9.23	93.32	8.56
Total	Classroom Discussion	54	89.60	8.26	90.32	8.66
	Assigned Group Roles	52	92.29	10.10	93.07	7.63
	Previous Instructional Practices	52	92.61	9.27	89.35	9.29
	Total	158	91.50	9.201	90.91	8.53

In order to test these differences statistically and answer the three sub questions, “Are there effects of the collaboration interventions on student collaborative problem solving, controlling for students’ pretest scores?”, “Are there effects of prior student experience with collaborative robotics on student collaborative problem solving, controlling for students’ pretest scores?”, and “Is there an interaction effect between the collaboration interventions and prior student experience with collaborative robotics on student learning motivation, controlling for students' pretest scores?", a 2x3 ANCOVA was applied with the pre collaborative problem solving scores as covariate. The ANCOVA indicated statistically significant main effects of interventions after controlling for students' pretest scores for collaborative problem solving, $F(2,140) = 5.09$, $p = .007$, $p < .05$, as seen in Table 7. The ANCOVA also indicated statistically significant main effects of the experience levels after controlling for students' pretest scores for collaborative problem solving, $F(2,140) = 18.51$, $p = .000$, $p < .05$. There was no statistically significant interaction between intervention and experience level, $F(2, 140) = 2.35$, $p = .099$, $p > .05$.

Table 7. ANCOVA for Post Total Collaborative Problem Solving

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4835.97a	6	805.99	17.49	.000
Intercept	3032.65	1	3032.65	65.81	.000
Pre Total Collaborative Problem Solving	2803.29	1	2803.29	60.83	.000
Interventions	469.09	2	234.55	5.09	.007
Experience Level	852.93	1	852.93	18.51	.000
Interventions * Experience Level	216.24	2	108.12	2.35	.099
Error	6451.93	140	46.09		
Total	1227867.00	147			
Corrected Total	11287.89	146			

a. R Squared = .428 (Adjusted R Squared = .404)

Examining the collaborative problem solving levels by intervention and experience level, it can be concluded that there is a statistically significant main effect for the interventions and experience level. The results of the ANCOVA called for a post hoc analysis for the three interventions using Tukey HSD to determine which conditions were statistically significant. Post hoc results in Table 8 indicate that the mean collaborative problem solving score for Assigned Group Roles were statistically different than Previous Instructional Practices, $p = .014$, $p < .05$. Taken together, these results indicate that the use of Assigned Group Roles has an effect on collaborative problem solving. Specifically, students in Assigned Group Roles had higher post mean collaborative problem solving scores when controlling for students' pre collaborative problem solving scores than students in both Classroom Discussion with a mean difference of 2.08 and Previous Instructional Practices with a mean difference of 3.98. However, there was only a statistically significant difference between Assigned Group Roles and Previous Instructional Practices. Overall, interventions and experience level produced statistically significant main effects, with Assigned Group Roles demonstrating statistically significant higher post mean scores for collaborative problem solving (93.07) than Previous Instructional Practices (89.35), as well as, Novice demonstrating statistically significant higher post mean scores (93.32) than Experienced (88.50).

Table 8. Post Hoc Test for Post Total Collaborative Problem Solving

(I) Interventions	(J) Interventions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Classroom Discussion	Assigned Group Roles	-2.06	1.53	.182	-5.09	.97
	Previous Instructional Practices	1.92	1.57	.223	-1.19	5.03
Assigned Group Roles	Classroom Discussion	2.06	1.53	.182	-.97	5.09
	Previous Instructional Practices	3.98*	1.60	.014	.81	7.15
Previous Instructional Practices	Classroom Discussion	-1.92	1.57	.223	-5.03	1.19
	Assigned Group Roles	-3.98*	1.60	.014	-7.15	-.81

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Research Question 3

In order to answer the third research question “Are there effects of the collaboration interventions and prior student experience with collaborative robotics on student science process skills, controlling for students’ pretest scores?” pre science process skills scores were used as a covariate and an ANCOVA was applied.

Science process skills were measured pre and post interventions and assessed to answer the third main research questions and its sub questions. A full score for science process skills was 45 points; however, scores for the students ranged from 0 to 9. Table 9 indicates that all intervention conditions for all the experience levels had increases in the post mean scores for science process skills with relation to the pre mean scores. However, higher gains were seen within the Novice level with all the post mean scores showing an increase of at least 1 point from 1.68 to 2.78. Assigned Group Roles also demonstrated an increase in post mean scores for science process skills from 2.35 to 3.45. Though these two conditions demonstrated the greatest increases, all conditions demonstrated an increase from pre mean scores to post mean scores.

Table 9. Condition Sizes, Means and Standard Deviations of Science Process Skills Scores

Experience Level	Interventions	N	Pretest		Posttest	
			Mean	SD	Mean	SD
Experienced	Classroom Discussion	26	2.12	1.28	2.89	1.67
	Assigned Group Roles	29	3.21	1.74	4.17	1.49
	Previous Instructional Practices	28	2.71	1.70	3.00	1.46
	Total	83	2.68	1.57	3.35	1.54
Novice	Classroom Discussion	31	1.77	1.06	2.79	1.29
	Assigned Group Roles	31	1.48	1.03	2.72	1.33
	Previous Instructional Practices	30	1.80	1.42	2.83	1.29
	Total	92	1.68	1.17	2.78	1.30
Total	Classroom Discussion	57	1.95	1.17	2.84	1.48
	Assigned Group Roles	60	2.35	1.39	3.45	1.41
	Previous Instructional Practices	58	2.26	1.56	2.92	1.38
	Total	175	2.19	1.37	3.07	1.42

In order to test these differences statistically and answer the three sub questions, “Are there effects of the collaboration interventions on student science process skills, controlling for students’ pretest scores?”, “Are there effects of prior student experience with collaborative robotics on student science process skills, controlling for students’ pretest scores?”, and “Is there an interaction effect between the collaboration interventions and prior student experience with collaborative robotics on student science process skills, controlling for students’ pretest scores?”, a 2x3 ANCOVA was applied with pre science process skills score as the covariate. The ANCOVA indicated no statistically significant main effects of interventions after controlling for students’ pretest scores for science process skills, $F(2,168) = 2.23$, $p = .11$, $p > .05$, as seen in Table 10. The ANCOVA also indicated no statistically significant main effects of the experience levels after controlling for students’ pre science process skills scores, $F(2,168) = .248$, $p = .619$, $p > .05$. There was no statistically significant interaction between intervention and experience level, $F(2, 168) = 2.16$, $p = .119$, $p > .05$. No post hoc tests were necessary as there was no statistically significant main effect for interventions or experience levels.

Table 10. ANCOVA for Post Total Science Process Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	120.71a	6	20.12	12.49	.000
Intercept	199.64	1	199.64	123.89	.000
Pre Total Scientific Process Skills	75.55	1	75.55	46.88	.000
Interventions	7.19	2	3.60	2.23	.111
Experience Level	.40	1	.40	.25	.619
Interventions * Experience Level	6.95	2	3.48	2.16	.119
Error	270.72	168	1.61		
Total	2027.00	175			
Corrected Total	391.43	174			

a. R Squared = .308 (Adjusted R Squared = .284)

CHAPTER FIVE: DISCUSSION

The purpose of this study was to determine if collaboration interventions and robotics experience levels could create an effect on student motivation, collaborative problem solving, and the development of science process skills while controlling for students' pretest scores. The findings for the collaborative robotics project in the elementary engineering lab demonstrated that Assigned Group Roles with a 1point increase produced statistically significant positive effects on measured student motivation in relation to Classroom Discussion and Previous Instructional Practices, which both demonstrated decreases from pre to post mean scores. Assigned Group Roles and Classroom Discussion demonstrated similar increases for collaborative problem solving. However, only Assigned Group Roles produced statistically significant positive effects on measured collaborative problem solving in relation to Previous Instructional Practices. The Novice experience level also demonstrated statistically significant positive effects on measured student motivation and collaborative problem solving in relation to Experienced. All conditions demonstrated positive effects on science process skills but not at a statistically significant level.

The Assigned Group Roles intervention included teacher reinforcement and a document outlining each role, Time Manager, Materials Manager, Project Manager, and Data Manager, as well as, detailed job responsibilities. The study's positive results support Yuen et al.'s (2014) emphasis of structure during collaborative group work. The four roles included some responsibilities that were the same, such as research, designing, building, and programming. In addition to each role having identical responsibilities, each role had unique responsibilities created to develop and promote collaboration between the four roles. The division and sharing of job responsibilities created structure for the Assigned Group Roles that supports Eguchi (2012) and Mills et al. (2013) recommendations for collaborative robotics work. The roles were developed for educational purposes to develop a wide range of skills in each student. Students were required to work on all areas of the collaborative robotics project rather than focusing solely on one area or on any areas of strength they may have had. While this use of group roles is contrary to Yuen et al. (2014) recommendations of focusing on students' areas of strength, the roles are used to promote new skills, as well as, developing existing areas of strength. Yuen et al. (2014) addressed collaborative robotics in an informal educational setting and had different instructional purposes for group roles. In the present study, the roles were also designed to balance quiet and dominant group members, as encouraged by Somyürek (2014). Rotating the roles weekly was established to further promote equal distribution of the work responsibilities. Student groups varied in their diligence to follow the Assigned Group Roles. While some students took the roles seriously and carefully followed the guidelines, other groups had to be reminded multiple times during class to follow the roles and perform their responsibilities. The positive results indicate that structure of the roles provided the necessary support and scaffold to meet the needs of the classroom setting while developing motivation and collaborative problem solving.

The Novice experience level had a clear positive effect on motivation and collaborative problem solving. Interestingly, research with experience levels in robotics suggests that the Novice students would have needed more supports than more experienced robotics students in order to recognize the same benefits (Eguchi, 2012), and yet, the Novice level demonstrated more positive effects. Though the increase for the Novice was less than two points, the Experienced had a decrease of more than two points. Perhaps the novelty of the collaborative robotics project could be responsible for higher post mean motivation scores. However, it is difficult to identify potential reasons for the differences in post mean collaborative problem solving scores. With two years of experience, post mean scores for collaborative problem solving should have been higher for the Experienced level, and yet the Experienced students showed a decrease in post mean scores while Novice students had a slight increase. Perhaps additional supports and interventions need to be identified to continue the growth of these skills for Experienced students.

The lack of any statistically significant difference in post mean scores for science process skills for interventions and experience level may be due to the overall low scores. With the potential for a total of 45 points, student scores ranged from 0 to 9. The low scores may not have allowed for large enough difference to successfully identify a statistical difference between the conditions. The Fowler Science Process Skills assessment was designed for middle school students. While some middle schools include fifth grade students, the instrument may not have been the most appropriate measure for students in fourth and fifth grades. The potential issue with the instrument appropriateness may have made it difficult to identify effects of the interventions or experience levels. Furthermore, the robotics project may not have made strong enough connections to the systematic scientific approach measured with the Fowler Science

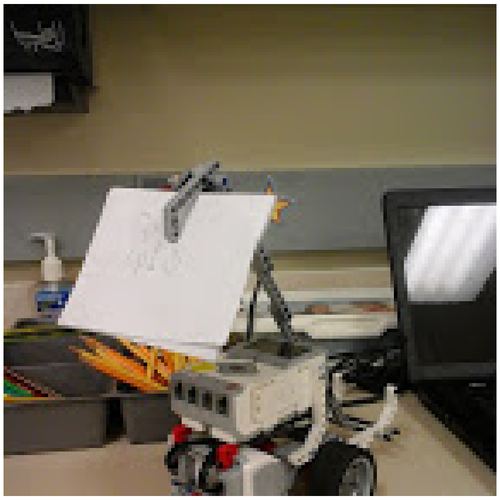
Process Skills assessment, resulting in a continued low range of scores even though students experienced overall increases in mean post scores.

All intervention conditions promoted student responsibility and minimized the teacher's role. The interventions allowed students to retain their ownership of the project and rely upon their group as recommended by Ucgul and Cagiltay (2014). The teacher assisted with group questions and dynamics as needed in all three of the intervention conditions. Teacher implementation of the interventions and experience levels supported Blumenfeld et al.'s (1991) claim of the importance of the teacher's role in problem-based learning. Choosing to implement and support a successful intervention can positively impact student benefits.

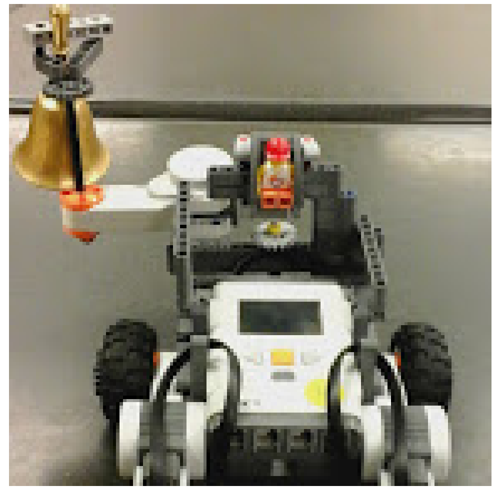
Limitations

Even though the study was conducted from mid-September 2015 through mid-January 2016, the nature of the class meeting, lasting only an hour each week, provided the students with only a total of approximately 16 hours to complete the robotics project, not accounting for absences. Stubbs, Casper, and Yanco (2012) suggest that shorter length programs may not make a significant impact that is capable of being captured on pre and posttest data. However, shorter time lengths is a common feature of the engineering class and the students were familiar with time constraints from various projects in the past. The reduced exposure may have limited the positive impacts for students. Nevertheless, the purpose of the study was to determine successful collaborative supports for group robotics projects in classroom. Time limitations is a real world constraint of the classroom with all the demands put on instructional time. While additional time may have yielded improved outcomes, it was still important to identify what could be achieved in the time afforded for the study. Hwang and Wu (2014) determined that collaboration proved to be the most beneficial instructional strategy for promoting completion of robotics tasks when limited time was available. In fact, benefits were identifiable in the present study, even within a limited amount of time and identified collaborative supports. In addition, the implementation of the collaborative robotics project and interventions could be duplicated in a classroom with existing time constraints.

Another consideration for the study was the differences between novice and experienced levels. In order to complete the study in a manageable time frame and examine both experience levels during the same 16 week time period, additional robotics kits were needed. Therefore, 28 of the 32 student groups in fifth grade, the experienced level, used the new LEGO Mindstorms EV3 kits rather than the NXT they used in the previous grade level. This required the learning of a similar yet new robot. The new robotics kits seemed to excite the students, but the use of the new EV3 software created some challenges for the groups given the limited time frame. Furthermore, students in the Experienced level may have underestimated the challenge involved in the robotics projects as some groups in Mills et al.'s (2013) study did. Therefore, their mean post scores for motivation and collaborative problem solving may have been lower due to a more realistic understanding of the project.



Picture 1. LEGO EV3 Build



Picture 2. LEGO NXT Build

The use of different robotics kit, EV3 and NXT as seen in Picture 1 and 2, and software may have impacted results between the Novice and Experience levels since the majority of the Experienced level were working with a new EV3 robotics kit and software. While the two robotics kits have many similarities and only slight differences, the similarities may not have been sufficient enough to counter the differences that had to be learned. The software differences consisted mainly of location for changing the programming blocks. Rather than being at the bottom of the screen as in the NXT software, the programming changes made to a block were at the bottom of the programming block itself. EV3 Mindstorms have similar sensors in function and appearance as compared with the NXT Mindstorms, however, the EV3 lacked the sound sensor that many students enjoy integrating. Running a downloaded program on the EV3 was a challenge initially for students. The design of the two robotics kits remained essentially the same with a brick for programming and additional parts to create a model with the brick. Some of the different components caused students to have to reevaluate their ideas for designing a solution. Nevertheless, the Experienced level still had prior experience with designing, building, and programming a robotic solution as compared to the Novice level. Even with the potential added challenge of the new robotics kits, the Experienced level had more groups that created original robotic designs, rather than modifying instructions, indicating a comfort level with the project and supporting Barak and Zadok's (2007) assertion that experts may find alternate routes rather than following a prescribed path from start to finish. In addition, the possibility exists that the Experienced level rated themselves higher originally because they had already completed a similar project in fourth grade. That project had been completed a year earlier. In addition, the fourth grade project may not have been as complex or required the same level of understanding. Therefore, when the Experienced level rated themselves on the post survey, their scores may have been more realistic than the pre survey, having just completed the collaborative robotics project. The differences in perspective before and after the project may have impacted the mean post scores for motivation and collaborative problem solving for the Experienced level.

The new students, who began attending the school in December 2015 near the completion of the study, were placed in groups and participated in all the components of the project from that point on. Due to the nature of the study, and the timing for the new students entering the school, pretests and surveys could not be conducted. There was only a net change of two additional male students in the fifth grade, one in the Assigned Group Roles intervention and the other in the Classroom Discussions intervention. Figure 2 identifies the original group sizes with one group of three becoming a group of four in both Experienced Assigned Group Roles and Experienced Classroom Discussion.

Understandably, the new students' comfort level were different given they entered the project near the completion, and so concessions were made to their involvement in presenting the project. They completed all other aspects of the project, including the data collection at the end. Their posttest data was not used in the results as they had no pretest data and had not experienced the interventions for the majority of the project.

The study was conducted by the elementary engineering teacher as the primary researcher. The elementary engineering teacher was also responsible for collecting and analyzing data as well as implementing the identified instructional practices. Teaching is a fulltime profession that already extends itself beyond the confines of the contractual work day. However, the nature of the study, identifying successful instructional practices, was well suited for a teacher/researcher since classroom educators may already gather data, reflect, and consider what strategies are successful in the classroom. Time management was critical to addressing the needs of the study and needs of the students concurrently. The research was simply one additional step in improving instructional practices rather than implementing a new curriculum and conducting a study. Therefore, time commitment required for both instruction and research was not a concern. The study was manageable as an extension of the existing instructional practices. The position of teacher/researcher provided familiarity with the instructional process and the collected data and removed any possible distractions or intrusions during the robotics project. Potential for bias exists with the teacher as researcher, after all, interventions would only be implemented with the belief that they would create learning benefits for students. However, there was no intentional bias towards any of the interventions or experience levels. None of the interventions had been used previously in the elementary engineering lab. Both Assigned Group Roles and Classroom Discussion had a structure that was followed routinely. Assigned Group Roles had the printed guidelines that limited the potential for research bias, and Classroom Discussion had a prescribed time and method for implementation that was followed to limit the potential for bias. Additionally, all three interventions and both experience levels completed the same instructional sequence to prevent any potential bias.

The present study was viable due to the resources and curriculum flexibility existing in the current program. With approximately 179 fourth and fifth graders enrolled each year, there was a sufficient sample size to support the quasi-experimental study. The support of the fourth and fifth grade teachers assisted the researcher in sending out and collecting Informed Parental Consent, which would have proved difficult without their assistance.

Potential Impacts

The goal for the study was to identify collaboration strategies for collaborative robotics projects that could impact student benefits, practices for classroom educators, as well as instructional theory. Assigned Group Roles was identified as a collaborative intervention that had positive effects on student learning motivation and collaborative problem solving. In addition, the study examined how student robotic experience level impacts student motivation, collaborative problem solving, and science process skills. The Novice level had positive effects on learning motivation and collaborative problem solving. The balanced rigor and relevance of the data and the results now have the potential to inform theories and practices (Reeves, 2011). Classroom educators and researchers alike could use this study to inform practices. The use of Assigned Group

Roles can be implemented for robotics projects to promote student benefits in a collaborative environment. The results in regard to Assigned Group Roles further supports Yuen et al.’s (2014) recommendation for collaboration to promote equal workload by all group members, increased motivation, and improved student achievement. Even with a natural variance in student adherence to the roles, students experienced positive effects. In addition, the roles could be adapted to be used with other collaborative problem-based projects. It is important to understand the educational goals for the use of group roles. The present study intended for students to experience a variety of roles and develop new skills, as well as, build existing skills.

As robotics grows in educational applications, understanding the impact of students’ developing experience can assist in the development of appropriate instructional guidelines and implementation strategies for robotics in the classroom setting. Novice students needed no more supports than the Experienced students to complete a robotic solution. Whereas research identified Novice students as needing more supports to assist students in successfully completing a collaborative robotics project, the results of the present study identified the need for more supports in order for the Experienced students to make desired gains in learning motivation and collaborative problem solving (Barak & Zadok, 2007; Blanchard et al., 2010; Eguchi, 2012).

Teachers may be more willing to implement robotics in the classroom if there is a ready-to-use instructional model and support to ease the implementation. The Assigned Group Roles can be modified and adapted to meet the educational goals of the teacher. The 16-hour instructional sequence provides a manageable time frame and sequence for potential implementation into a general classroom setting. In addition, the identified results may increase teachers' desire to implement robotics with the benefits to students. Collaborative problem solving skills and learning motivation are critical for a variety of subject areas.

Conclusion

Galileo STEM Academy has the robotics resources available to provide robotics instruction in the elementary engineering lab and for after school groups. The breadth of knowledge covered through collaborative robotics projects fits easily within the engineering curriculum and meets the Next Generation Science Standards. While the general method of instruction for collaborative robotics projects had promoted student benefits, there was a need to evaluate the general method of instruction and determine if collaborative interventions could improve student outcomes. Additionally, with students using a form of robotics as early as first grade and the Mindstorms as early as third grade, understanding how to support the developing experience levels is critical for on-going robotics instruction and development of an appropriate scope and sequence. The present study opens the door for developing a model to promote a collaborative environment that fosters skills necessary for STEM success, such as student motivation, collaborative problem solving, and science process skills.

The results indicate that the Assigned Group Roles had a positive effect on student motivation and collaborative problem solving. While Assigned Group Roles had not been previously used in the elementary engineering classroom for previous projects, it will be used in future instruction and adapted for use with other collaborative projects. In the present study, Assigned Group Roles was the only intervention that had printed guidelines for students to keep in their Engineering Notebooks. Perhaps a printed guideline for Classroom Discussions could be included in the intervention to offer appropriate sentence starters, questions, and reminders about classroom interaction expectations in order to better support that collaboration strategy.

Robotics experience level also played an important part in student motivation and collaborative problem solving. The positive effects for the Novice level consistently outperformed effects for the Experienced level. Understanding the supports needed for the varying experience levels is important in order to implement the appropriate instructional practices. It appears that additional supports are necessary for the Experienced level students in order for them to continue to make gains in learning motivation and collaborative problem solving. Post mean motivations scores only showed an increase in the Experienced level for Assigned Group Roles, and the increase was as minimal as .05 points. Only Classroom Discussion from the Experienced level had increased post mean scores for collaborative problem solving; however, not at a significant level. Overall additional investigation into supports for Experienced students is warranted.

The identification of successful collaboration intervention for collaborative robotics projects fills a practical and growing need of robotics integration into the educational setting. In fact, the relevance of the study to student learning also added to the rigor (Reeves, 2011). This study was relevant to teaching, learning, educational outcomes, as it addresses the educational needs of learners, practitioners, designers, and society by promoting collaborative problem solving skills and learning motivation (Reeves, 2011). Furthermore, the study has the potential to provide instructional insights for various problem-based collaborative environments.

The study was conducted in an authentic contextual setting to determine how best to support collaborative robotics projects. Additional studies could be conducted to determine how to develop classroom discussions to produce a more consistent benefit to students. Using claims, evidence, and reasoning in discussions to construct explanations may support the collaborative nature of the robotics project by reducing the potential for personal opinion to enter the discussions. Furthermore, the claims, evidence, and reasoning discussion format supports the systematic scientific approach desired for scientific process skills. While this project did not allow for the time development of building and supporting an arguments strategy, this would be advantageous to use for collaborative group projects and may be implemented in future iterations with a discussion focus on evidence and claims. Further research could also be conducted to improve upon the Assigned Group Roles. What aspects of the roles produced the benefits seen in the existing study, and how could those benefits be improved upon? Replications of the existing study would also be beneficial to determine if the results could be duplicated. Would classrooms with students who had participated this year see less statistically significant difference? Would the same differences by experience level still be apparent? If so, what intervention could improve the outcomes for the Experienced level? Would a combination of Classroom Discussion and Assigned Group Roles create the same positive effect for collaborative problem solving and motivation? Perhaps it would be possible to improve the size of the increase in post mean scores by combining the two interventions. Future research has the potential to benefit not only robotics instruction, but collaborative learning as well.

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APPENDIX A

Lesson Plans for Robotics Project

Lesson Plans for Robotics Project

Next Generation Science Standards
Grades 3-5
At the upper elementary grades, engineering design engages students in more formalized problem solving. Students define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given problem. Generating and testing solutions also becomes more rigorous as the students learn to optimize solutions by revising those several times to obtain the best possible design.

Students who demonstrate understanding can:
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Common Core English Language Arts Standards » Speaking & Listening »
4th Grade
CCSS.ELA-LITERACY.SL.4.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.4.1.B - Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.4.1.C - Pose and respond to specific questions to clarify or follow up on information, and make comments that contribute to the discussion and link to the remarks of others.
CCSS.ELA-LITERACY.SL.4.4 - Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
CCSS.ELA-LITERACY.SL.4.5
Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes.

5th Grade
CCSS.ELA-LITERACY.SL.5.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.5.1.B - Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.5.1.C - Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.

CCSS.ELA-LITERACY.SL.5.4 - Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
CCSS.ELA-LITERACY.SL.5.5 - Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

Note: Additional cross-curricular standards can be addressed dependent upon the criteria established for the project. This project was conducted during one hour weekly classes. The project could be condensed in time dependent upon the classroom time available.
Prerequisites: Students have received basic instruction in programming and use of the robot prior to beginning the robotics project. Novice level had received only rudimentary instruction in basic programming of the robot to move forwards and backwards and make point and curve turns. Experienced level received instruction in moving the robot and using sensors. In addition, the experienced level had completed a robotics project in the previous year. Both levels went through the same lesson plans.

Project Criteria/Constraints:
Students will work within their groups to identify a problem in the school and then develop a robotic solution to solve the problem. The robot has to be programmed to perform some motion even though it does not need to move like a vehicle. The robotic solution can only be built from the robotics kits the students are provided with. No additional parts can be used. Student may use other materials for the purpose of demonstration. For example, if the robot is designed to collect garbage, students are allowed to use balled up paper or blocks to represent to garbage being cleaned up. In January, students will present in their groups the process they followed to develop their robotic solution and demonstrate their working robotic solution. While the final goal is to demonstrate a working solution, issues may arise to prevent a group of reaching that goal, just as in real life. Students can still achieve an on-grade-level score for the project if they present the process and identify the issues that prevented them achieving a working solution. Groups should also be able to explain what the robotic solution was intended to do and have demonstrated consistent effort and participation during each class. Students will be graded by the teacher during each class for their effort and participation, and at the end of the project for the completion of the process. The final evaluation at the end of the project will involve student self-assessment through the use of student-generated rubrics by each class. Four rubrics will be on each paper between the front and back. Students will use one paper to evaluate themselves and their group members. The teacher will use the same rubric to evaluate each student individually.

Materials:

8	–	Laptops (One for each group in a class. These can be shared between classes.)
		LEGO Mindstorms software installed on each computer (EV3 and NXT)
48	–	LEGO Mindstorms robotics kits (One for each group. Eight for each class.)
187	–	File folders set up for student Engineering Notebooks
		Graph paper for use in the Engineering Notebooks
		Pencils, colored pencils, crayons for Engineering Notebooks
		Online robotics resources – See Appendix E

Week 1 - Lesson 1: Project Introduction

Establish groups:
Within the classroom, eight work areas have been established and a number from 2 through 9 is hanging about each work area. A deck of card has all other cards but the 2s through 9s removed from the deck. Shuffle the cards and have the students draw a card as they enter the classroom to establish the groups for the project. If there is a group of only two students, another student from a group of four will need to be moved. Groups should consist of three to four students. Three is recommended, but class size and materials for this study dictate that the majority of the groups are groups of four students as noted in Figure 2. These will be the groups for the duration of the project. The random assignment alleviates students wanting to be with their friends and frees students and teacher alike from blame assignment for the structure of the groups.

Introduce project:
Have the students collect their Engineering Notebooks from the front of the classroom before sitting down in their project groups. Explain to the class that today they will be starting a new project. They will be identifying a problem in the school and then designing a robotic solution to solve the problem. Ask "What do we need to know to complete this project?" Write down students ideas. It may take additional wait time for students to begin generating ideas. Ideas for what is needed may vary. Address the ideas by asking students what resources they already have and where can they find additional resources. Initially students may indicate the teacher as the additional resource. Encourage students to think of alternative resources to the teacher.

Administer Pre-assessments:
Pre-assessments are required for this project due to the nature of the study. Give directions whole class for the Fowler Science Process Skills Assessment and Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey while the assessments are under a document camera and available for all to see. Handout both assessments to the students at the same time and recommend that they start with the survey since it is two-sided. Help monitor time for students who are still working on pre-assessments to ensure completion of both. Check papers for completion as they are handed in. Some students miss the second side of the survey. Students also may ask if they can circle in between the numbers on the Likert scale for the survey. Just have them choose the one they feel they are closest too.

Brainstorm problems and solutions:
As students complete and turn in both of their assessments, they can begin to independently brainstorm problems around the school silently in their Engineering Notebook to share with their group when everyone has completed their pre-assessments. They should not be contemplating solution ideas and may need to be reminded of this. Some students may not reach the brainstorming point by the end of class.

Teacher Notes:
During this lesson, no differences are identifiable between intervention conditions. Students have already been introduced to the use of the Engineering Notebooks. Have students add Robotics Project to their table of contents and create a new page labeled Robotics Project with

the date. Engineering Notebooks are collected at the end of each class and do not leave the classroom. Record group table numbers and the student names.

Week 2 – Lesson 2: Robotics Kits

Have the students come in, collect their Engineering Notebooks, and sit down in their groups. Explain to the class that once the groups develop 10 problem ideas between them and chose one or a combination of ideas, they will get their robotics kits. Kits are labeled on the bottom of the tub, the lid, and the brain or brick of the robot with matching numbers such as A1. This helps keeps various parts together and assist in correcting mix-ups. When the students get their kits they will have another opportunity to divide up the labor and practice their collaboration skills. The kit will need to be counted and all the parts inventoried and verified. This is most efficiently accomplished if students equally distribute the workload among all the group members. Explain that the bottom tub of the NXT is easiest to count and the top tray will require more time. Students should use the parts cards to match the tray sections and parts as well as identifying the number of parts. The EV3 has no divisions on the bottom section of the tub, and the parts for the bottom section are on the bottom of the tub. Recommend to students that they count out the bottom parts in the tub lid so the bottom parts card is still visible. Explain to the students that it is important they count and inventory all their parts in their kits because they will only be able to use the parts they have in their kits for designing their robotic solution. If they miscount or misplace any parts during the project, they will not be able to get replacement pieces. Give the time that groups need to be cleaned up and seated quietly at their tables. This may vary depending on the group and as the groups learn the cleanup procedures, but will help the groups with planning their activities for the class. Classroom Discussion classes should have approximately ten minutes at the end of class for whole class discussion time. Other classes may need only five minutes to record additional notes in their Engineering Notebooks. Remind students to record notes in their Engineering Notebook if they have not already done so during class. Give examples of what might be included at this point in their notebooks. All group members should be writing down their robotics kit number and their laptop number once they are assigned so that all members have the information even if a student is absent.

Teacher Notes:
During this class, monitor student group interactions as they brainstorm problems and choose one. Promote sharing of the workload and giving everyone a turn. Inventorying of the robotics kits is to help develop familiarity with the parts available within the kits and promote generation of ideas for robotic design. It also promotes accountability for the kits and reduces the amount of misplaced parts. Remind students to record notes in their Engineering Notebook. As kits and laptops are assigned to groups, record the numbers in case groups misplace their information.

Classroom Discussions:
At the beginning of class, ask for student explanations about the project. Ask if there are any concerns. Model wait time and rephrasing or restating students' concerns. Ask other students to restate concerns of student volunteered responses. Check for clarification from students if the restating or rephrasing of the concerns was correctly stated. Model wait time when checking in with the groups. Give them time to gather their ideas to share with the teacher. Model rephrasing by restating their ideas and double checking for clarification that it was restated

correctly. Have students clean up and be seated quietly so that there are ten minutes to model and reinforce discussions.

Assigned Group Roles:
Handout the Assigned Group Role sheet to all the students at the beginning of class. Explain that students will be taking on a designated role each class and that it will change each class. Ask for students to identify similarities and differences between the roles once they have been read through as a class. Ask which role is the boss of the group. Wait for responses and explain that no role is the boss of the group. They all work together and share the workload equally just with different emphasis. Group consensus is still required and necessitates group discussion. Group roles will be assigned based upon the seat students occupy at the table. For example, all the students sitting at the table in the front left seat of the table will be the Time Manager. Group roles will be assigned continuing down the list moving counter-clockwise around the table. Any students that are absent will be marked down by the group for the role they would have had, but the tasks for the absent student will be divided amongst the other group members. If there are only three members in the group, one role will always be shared throughout the project. After this class, students will simply rotate through the list no matter what seat they occupy at the table. Before proceeding with class, ask all the Time Mangers to raise their hands. Confirm the correct students have their hands raised. Continue the same way through all the roles. Address any student questions about their role for the day. Confirm that the Time Managers know what time their groups need to be cleaned up. This is not the same as starting clean up.

Week 3 – Lesson 3: Design and Build

Have the students come in, collect their Engineering Notebook, and sit down in their groups. Groups continue to decide on solution if necessary, develop design, and begin to build their robotic solution. Recommend that the groups should try and decide upon a solution by the end of the lesson in order to have more time for building and programming. As students decide upon a potential solution they may want to research potential builds on the internet based upon what they would like their robotic solution to do. Remind them to search for build instructions based upon their kit number and to include their kit number in the search bar. Groups may get their robotics kit when they have decided on the solution and the design for their robotic solution. Groups will also be assigned a laptop for use of researching designs and program their robot. Students may access their laptop as needed. To facilitate more success in building of the robot with limited or no experience in this area, students are allowed to build from instructions and add an original aspect to the robot that is functional and not merely decorative. The use of instructions given the limited time for the project will enable students to experience building and still have sufficient time for programming, testing, and improving. If students have accessed their robotics kits, remind them to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. Laptops need to be returned to the counter and reconnected to their charging cords. If students have started building, they should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to record notes in their Engineering Notebook if they have not already done so during class. Ask for volunteers that would like to share a note from their notebook.

Teacher Notes:
Groups will begin to have greater variance in their progress. As groups begin building their robotic solution remind the students that all the group members should be helping with the building, rotating turns throughout the class. Some students will want to divide it in pairs between half the group for half the class time. This often leaves the second students with little or no building time. Groups that do not heed the warning about checking and charging their robots will learn an important lesson when they cannot program because the battery is too low. Repeat the reminder at the end of each class.

Classroom Discussion:
At the beginning of class ask the students what is going well in their groups. Are there any challenges? Share the positive and see if other groups have ideas for the challenges. Model the wait time, restating, and constructive feedback that positively addresses the stated problem. Maintain a respectful attitude with the students and redirect student discussion participants that may not maintain a respectful attitude. Encourage other students to offer suggestions for any challenges groups may be experience. Assist students in keeping the discussion focused on the project and leave individual students or personal aspects out of the discussion. Mid-way through the class, check in with the groups via another whole class discussion. At the end of class, take the opportunity one more time to share successes and challenges and reinforce the different discussions skills being targeted.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. They should have simply moved down one role on the list. Review the tasks for each role. Address questions and reaffirm the similarities and differences between the roles. Remind the students that no one role is the boss of the group. All roles should be helping with the building, rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group.

Week 4 – Lesson 4: Design and Build

Have students come in, get their Engineering Notebooks, and sit in their groups. Once the initial review of information is completed, students may get their assigned robotics kits from the storage cupboards and laptop if needed for building instructions. Groups continue to develop design, build their robotic solution, and possibly begin programming. Some groups may be ready to begin programming. Students will use the Mindstorms software installed on the laptops to program their robot. Both the EV3 and NXT software. Give a brief review of the software, or in the case of the EV3 software, a brief introduction. When introducing the EV3 software demonstrate the similarities between the NXT software to promote students' confidence in using the new software. Groups that have not started building need to be prompted to choose a design and begin building. Visit with each group to confirm that their build instructions can be completed with the robotics kit they have and to assess group progress. When starting cleanup, remind students to make sure all the parts are picked up, check the floors, and check the table tops before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords.

If students have started building, they should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to record notes in their Engineering Notebook if they have not already done so during class. Ask for volunteers that would like to share a note from their notebook.

Teacher Notes:
Continue the routines for the beginning of class and the cleanup process. The routines will eventually reduce the amount of time needed to review the project requirements and for cleanup as well as confusion and mix-ups during the cleanup. Any robotics parts found after the class has left do not get returned to the students, but can be collected for the end of the project when students are inventorying their kits again.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. The time during the middle of class can be just a quick check in with more time spent at the beginning and end of class for whole class discussions. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. They should have simply moved down one role on the list. By this class students should be on their third role since roles were not implemented during the first lesson. Review the tasks for each role. Address questions and reaffirm the similarities and differences between the roles. Remind the students that no one role is the boss of the group. All roles should be helping with the building, rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group.

Week 5 – Lesson 5: Design and Build

Have students come in, get their Engineering Notebooks, and sit in their groups. Groups continue to build their robotic solution. More groups may be ready to program. As groups begin to program and test their robotic solutions, it is important to remind them how to make changes. Groups may find that changes need to be made to the design as well as the program. Changes both to the program and the design should be "baby steps." Make one small change and then test. Students should repeat this process as needed to resolve issues with design or program. After these reminders, groups can collect their robotics kits and laptop if needed. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Students using the NXT robotics kits need to return their download cords to the appropriate drawer. EV3 kits have a different download cord and should keep their cords in the bottom of their robotics tub. No download cords should be left connected to the laptops. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to record notes in their Engineering Notebook if they have not already done so during class.

Teacher Notes:
The teacher needs to continue reviewing the criteria of the robotics project to help the students stay focused on the final results. It is important to continue checking in with each group and monitoring progress in addition to assisting groups as difficulties arise. If there is time, ask several students to view their notebooks.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. The time during the middle of class can be just a quick check in with more time spent at the beginning and end of class for whole class discussions. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. They should have simply moved down one role on the list. By this class students should be on their fourth role. Review the tasks for each role. Address questions and reaffirm the similarities and differences between the roles. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group. Verify with the viewing of the notebook that Data Manager is meeting the expectations of their assigned group role.

Week 6 – Lesson 6: Programming and Improving

Have students come in, get their Engineering Notebooks, and sit in their groups. Some groups may still be building, but many of the groups will be starting to program and test the robotic solution, making improvements as time allows in both design and program. Address any questions, and then have students gather the group materials. Remind students to make small changes to the design and program as necessary and test immediately after making the change before making any additional changes. During cleanup remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords need to be disconnected from the laptops and put in their appropriate places. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter.

Teacher Notes:
It is important to monitor group interactions and progress. However, it is also important to help the students develop their own answers to issues with the robotic solution by identifying the resources they have available to them rather than seeking answers from the teacher. Continue monitoring groups but remain as an observer if possible. A clipboard with groups and student

names is also helpful to carry around to note progress. These notes can also assist in giving the grade each class for effort and participation for each student.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. The time during the middle of class can be just a quick check in with more time spent at the beginning and end of class for whole class discussions. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. They should have simply moved down one role on the list. By this class students should be repeating their first role. Give a brief review the tasks for each role. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group. Verify with the viewing of the notebook that Data Manager is meeting the expectations of their assigned group role.

Week 7 – Lesson 7: Programming and Improving

Have students come in, get their Engineering Notebooks, and sit in their groups. Students begin or continue to program and test their solution, making improvements as time allows in both design and program. Review criteria for the project before having the students gather their materials. At this point in the project, it is important to explain to the students how much time they have left to complete the project to assist the groups in their planning. During cleanup remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords need to be put away in appropriate locations. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to write in their Engineering Notebooks if they haven't yet for this class.

Teacher Notes:
Continue to check in with each group during class and reinforce everyone in the group taking turns programming. If there are any groups you did not have time to visit with during the previous class be sure to start with those groups when checking in with the different groups. Every time the program changes a different person should be making the change. Every time the robot is run a different person should be running the robot. This is not a choice. It is not an option to take three turns and then change. Every time they should be rotating through the group members who is completing the task. By this lesson students will be getting more at ease with the process and the procedures.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. The time during the middle of class can be just a quick check in with more time spent at the beginning and end of class for whole class discussions. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group. Check in with a different assigned group role other than the Data Manager this week.

Week 8 – Lesson 8: Programming and Improving

Have students come in, get their Engineering Notebooks, and sit in their groups. Students continue to program and test solution, making improvements as time allows in both design and program. Explain to the students that even though they may be getting close to a working solution. They should continue to make improvements and work to make their program more efficient if possible. It is important to tell the students that if they have a working program they should create a copy of it by saving it as another version of the same file name, and then making changes to the copy. This will allow them to have a working program even if their changes possibly negatively affect the program. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords need to be put away in their appropriate areas. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to write notes in their Engineering Notebooks.

Teacher Notes:
Visit with any groups that may not have begun programming. Reassure them that they are still doing fine if they have been consistently giving their best effort and actively participating. Students that may have had issues with participating appropriately in their group should be notified if their class grade for that day is being impacted.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. The time during the middle of class can be discontinued with time for discussions only at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group. Check in with a different assigned group role this week.

Week 9 – Lesson 9: Programming and Improving; Design Student-Developed Evaluation Rubric

Have students come in, get their Engineering Notebooks, and sit in their groups. Students continue to program and test solution, making improvements as time allows in both design and program. Before students get started for the class, review the criteria for the collaborative robotics project. Have the students brainstorm and develop criteria for a student-generated rubric for evaluation of the completion of the process. Students and the teacher will use this rubric for evaluation purposes at the end of the project. Record the information for writing up the rubric for the class. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords need to be put away in their appropriate areas. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to write notes in their Engineering Notebooks.

Teacher Notes:
Outside of class time use the recorded rubric information to develop the rubric for the class. Guidance may be given with reminders of the project criteria during the development of the rubric. Continue to visit with each group and monitor progress.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. Visit with each group to confirm the roles are being implemented according to expectations. Address any discrepancies with each group. Check in with a different assigned group role this week.

Week 10 – Lesson 10: Programming and Improving; Finalize Student-Developed Evaluation Rubric

Have students come in, get their Engineering Notebooks, and sit in their groups. Students continue to program and test solution, making improvements as time allows in both design and program. Before the students begin working on their projects, project the developed rubrics to verify they meet the students' understanding and expectations. Address any questions and note any areas that may need revising. Students can then gather their materials and begin working. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords should be put away in the appropriate locations. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to record their notes in their Engineering Notebook if they have not done so already.

Teacher Notes:
Continue to visit with each group and monitor progress. Prepare the finalized rubrics and print a copy for each student to place in their Engineering Notebooks.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns.

Week 11 – Lesson 11: Continue to Test and Improve; Begin Preparing Presentation

Have students come in, get their Engineering Notebooks, and sit in their groups. During this class, groups will continue the iterative process of testing and improving their robotic solution. However, groups will also begin to prepare a digital presentation for the end of the project. Explain to the students that each group will have approximately five minutes to present the process they have gone through identifying a problem in the school all the way to developing a robotic solution to solve the problem. Presentations should include the steps completed to finish the project and successes and challenges. Following the presentation, groups will demonstrate their robot. Presentation and demonstration combined can be no longer than five minutes. Presentations will take place according to group/table number. Groups need to be ready to go as soon as the group before them is finished. All group members need to participate in the presentation. If groups did not complete a working robotic solution, it will be important for their presentation to include ideas about why the solution wasn't completed as well as ideas for completing the task next time. Address any questions and clarify as necessary. Student will be able to choose from a variety of digital sources for creating their digital presentation. Microsoft PowerPoint, Animoto.com, Microsoft Sway, video, Paper Slideshow, or other appropriate method for creating a digital presentation. All methods for creating the presentation have to be teacher approved. Some resources may be blocked for students. Students can use their laptop or a tablet for developing their presentation. Groups will be assigned a tablet number if necessary. Then groups can begin to work. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Download cords should be put away in the appropriate locations. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Remind students to record their notes in their Engineering Notebook if they have not done so already.

Teacher Notes:
Groups can put together whatever type of presentation that works for the classroom teacher. Digital presentations can be shared with families if permission slips are returned for all the group members. Otherwise, parents may come in before or after school to view the student presentation with teacher assistance. Furthermore, digital presentations do not require any storage space within the classroom. However, technical difficulties can issues during the presentation preparation and the final presentation. Continue to check in with groups so assess student understanding of the presentation and sharing of the workload.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. The presentation should be prepared and presented by all the group members still rotating the testing and improving as well as the presentation preparation through all the group members.

Week 12 – Lesson 12: Continue to Test and Improve; Continue Preparing Presentation

Have students come in, get their Engineering Notebooks, and sit in their groups. Remind students they have today and two more classes to finalize and practice the digital portion of the presentation. They only have one class after today to test and improve their robotic solution. Explain to the students that it is important to plan their tasks for today with that in mind. Ask a student to tell one aspect that should be included in the presentation. Continue on until all aspects are reviewed. Groups may get any of their assigned materials they need. Testing and improvement should continue on while the presentation is being prepared. Remind students to make sure all the parts are picked up before putting away their kits. The robot can fit beside or on top of the kit tub. Students should not touch other students' projects without permission. Laptops need to be returned to the counter and reconnected to their charging cords. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter.

Teacher Notes:
Continue to visit groups and provide guidance as needed in order to help the groups be prepared by the time the groups make their presentations. Groups may need more time to continue to improve their robotic solution. This portion of the project could be extended for two more classes instead of just one if necessary. Remind students that may be concerned about a non-working robotic solution of the presentation aspects to cover and reassure them they can still achieve an on-grade-level score for the project.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. During the review of the aspects a new strategy could be used to have the students turn to the student next to them and tell the different aspects of the presentation and then share out with the class until all of them are reviewed. It is not necessary to introduce a new strategy, but it is an option. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. The presentation should be prepared and presented by all the group members still rotating the testing and improving as well as the presentation preparation through all the group members.

Week 13 – Lesson 13: Continue to Test and Improve; Finalize Presentation

Have students come in, get their Engineering Notebooks, and sit in their groups. Groups will have this last class to test and improve their robotic solution and finalize their digital presentations. Students will have time to only practice their digital presentation during the next class, not prepare it. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter.

Teacher Notes:
Continue to rotate throughout the groups and confirm that groups are meeting expectations. Address any questions or concerns. It is important to make it through all the groups during the class time.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the building and/or programming rotating through turns. The presentation should be prepared and presented by all the group members still rotating the testing and improving as well as the presentation preparation through all the group members.

Week 14 – Lesson 14: Finalize Project and Presentation

Have students come in, get their Engineering Notebooks, and sit in their groups. Groups will use this class to practice and fine tune their presentation and robotic solution demonstration. Remind students to make sure all the parts are picked up before putting away their kits. Large chunks of builds can usually fit within the bottom of the tub to reduce the confusion and loss of building pieces. The robot can fit beside or on top of the kit tub. Laptops need to be returned to the counter and reconnected to their charging cords. Groups should check the battery level of their robot. If less than half full, the robot should be placed on an available charger along the counter. Making sure the battery is charged is critical for a successful demonstration. Robots may perform differently with a low battery. Explain to students that next class, they will come in, get their Engineering Notebooks, all their materials, and prepare to present. Groups will present in numerical order based on their table numbers starting with two and ending with nine.

Teacher Notes:
Continue to rotate throughout the groups and confirm that groups are meeting expectations. Develop a list of the method for each group’s digital presentation to make preparations to assist with the flow of the presentations in the next class. Address any questions or concerns. It is important to make it through all the groups during the class time.

Classroom Discussion:
Continue to model and reinforce strategies from earlier classes with time at the start, during the middle, and at the end of class. Classroom discussions will only be at the beginning and end of class. Continue to check in with each of the groups during class to assess group interactions and provide additional modeling and reinforcement of discussion strategies.

Assigned Group Roles:
Begin the class with having the students identify their role for the class. Remind the students that no one role is the boss of the group. All roles should be helping with the presentation and rotating through turns of demonstrating the robotic solution. The presentation should be prepared and presented by all the group members. The Time Manager can assist in practicing the presentation by observing the time requirements of a maximum of five minutes for both the presentation and demonstration.

Week 15 – Lesson 15: Present Project and Demonstrate Robotic Solution

Have students come in, get their Engineering Notebooks, gather their needed materials, and sit in their groups. Remind students to be a respectful audience and that recording of the presentations will be taking place. They need to be as quiet as possible so that only the students presenting are heard. Start the presentations as quickly as possible and hold the groups to the time maximum.

Teacher Notes:
Have all the necessary methods pulled up and ready on the computer connected to the projector. Have rubrics ready for each student to be able to quickly mark during the presentation for the appropriate sections. With eight groups in each class, groups has a maximum of five minutes for presentation and demonstration. This leave a total of 20 minutes for setup and cleanup between groups. Each presentation will be recorded and shared with parents following collection of parent permission slips to allow other families to view videos. For groups with students who did not return permission slips, parents may come to the school and view the video. The videos may also be used to complete any corresponding sections of the rubric for each student within the group.

Classroom Discussion:
Discussions will take place next class in the form of a wrap-up and feedback about the project.

Assigned Group Roles:
Roles will not be relevant for this class since all the parts of the presentation have already been practiced with specific group members.

Week 16 – Lesson 16: Post-Assessments and Wrap-up

Have students come in, get their Engineering Notebooks, and sit in their groups. Give post-assessments, Fowler Science Process Skills Assessment and Robotics Expo 2012 [Pre CEENbot] - Adapted 2015 Student Survey. In addition, students will evaluate themselves and their group members using the Student-Designed rubrics. As students complete their posttest and post survey, they can begin to disassemble their robotic solution and then inventory the parts. The kit needs to be completely inventoried before the group can be done. Have a class discussion about the project. Take input from the students about what worked and what didn't. Remind the students to be respectful about all the hard work everyone has put into the project. Discussions should only be about tasks, not about people.

Teacher Notes:
Write down student thoughts about the project to consider during the development of next year's project.

Week 17 – Lesson 17: Inventory Kit

Groups that are not finished with their inventorying of their robotics kits will need to complete it during this class. Other groups that are finished will work independently to review building techniques for their grade level materials and build a new build from instructions.

Teacher Notes:
This class may be necessary for some groups to complete the kit inventory. While it may be difficult to take this time, it can also be difficult for the teacher to count all the kits. There may be alternatives such as teaching assistants. However, it reinforces responsibility and accountability for the students to complete the inventory task. Students from the groups that have completed their inventory can work on any other lesson during the class time. Students in the elementary engineering lab would build with their grade level materials since it has been sixteen weeks since they used them.

Possible Problem Solving Questions for the Teacher during Programming:

If the program will not download in the NXT version of the software, ask
"Is your robot turned on?"
"Is your computer and robot connected with the download cord?"
The NXT software will clearly identify errors in downloading software.
The EV3 software will not let you download if the robot is not on or connected. The download option will be grayed out until both those conditions are met.

Students will complain that they keep changing their program but it runs the same.
"Are you sure you are running your program?"
"How do you know?"
"What is the name of your program?"
"Is that what shows on your robot's screen?"
Often times, students will leave the program with the generic name and then they are actually changing their program but running the wrong file.

Students can't find their file on the robot.
"Did you go into My Files before downloading your program?"
"Have you tried backing out of the files and going back in?"

Sample Completed Student Projects:

Picture 3. EV3 HappyBot

Picture 4. EV3 Snack Holder

Picture 5. NXT Trashanator

Picture 6. EV3 Litter Collector

Student Generated Rubrics for Robotics Project

4th Grade – Assigned Group Roles

	4	3	2	1
Effort	Usually had continued good effort day-to-day.	Often had good effort.	Sometimes had good effort.	Rarely had good effort
Participation	Usually listened to others, had a good attitude, shared ideas, was willing to do whatever jobs needed to be done.	Often listened to others, had a good attitude, shared ideas, was willing to do what was needed.	Sometimes listened to others, had a good attitude, shared ideas, was willing to do what was needed.	Rarely listened to others, had a good attitude, shared ideas, was willing to do what was needed.
Problem Solving	Usually identified a problem, developed a design, used creativity, tested and improved the robot.	Often identified a problem, developed a design, used creativity, tested and improved the robot.	Sometimes identified a problem, developed a design, used creativity, tested and improved the robot.	Rarely identified a problem, developed a design, used creativity, tested and improved the robot.
Share Results	Clearly explained the project process. Included what worked and what didn't. Presented on how the robot was built.	Explained the project process. Included some of what worked and what didn't. Presented on how some of the robot was built.	Explained very little of the project process. Included very little of what worked and what didn't. Presented very little on how of the robot was built.	Did not explain the project process. Did not include what worked and what didn't. Did not present on how the robot was built.

4th Grade – Classroom Discussion

	4	3	2	1
Effort	Usually did their best. Usually demonstrated perseverance.	Often did their best. Often demonstrated perseverance.	Sometimes did their best. Sometimes demonstrated perseverance.	Rarely did their best. Rarely demonstrated perseverance.
Participation	Usually shared work equally. Usually stayed on task.	Often shared work equally. Often stayed on task.	Sometimes shared work equally. Sometimes stayed on task.	Rarely shared work equally. Rarely stayed on task.
Problem Solving	Usually developed a solution and continued working on it, thought their way out of difficulties, used time efficiently, programmed the robot, used their creativity.	Often developed a solution and continued working on it, thought their way out of difficulties, used time efficiently, programmed the robot, used their creativity.	Sometimes developed a solution and continued working on it, thought their way out of difficulties, used time efficiently, programmed the robot, used their creativity.	Rarely developed a solution and continued working on it, thought their way out of difficulties, used time efficiently, programmed the robot, used their creativity.
Share Results	Clearly explained the project process.	Explained the project process.	Very briefly explained the project process.	Did not explain the project process.

4th Grade – Previous Instructional Practices

	4	3	2	1
Effort	Usually had continued good effort day-to-day.	Often had good effort.	Sometimes had good effort.	Rarely had good effort
Participation	Usually listened to others, had a good attitude, shared ideas, was willing to do whatever jobs needed to be done.	Often listened to others, had a good attitude, shared ideas, was willing to do what was needed.	Sometimes listened to others, had a good attitude, shared ideas, was willing to do what was needed.	Rarely listened to others, had a good attitude, shared ideas, was willing to do what was needed.
Problem Solving	Usually identified a problem, developed a design, used creativity, tested and improved the robot.	Often identified a problem, developed a design, used creativity, tested and improved the robot.	Sometimes identified a problem, developed a design, used creativity, tested and improved the robot.	Rarely identified a problem, developed a design, used creativity, tested and improved the robot.
Share Results	Clearly explained the project process. Included what worked and what didn't. Presented on how the robot was built.	Explained the project process. Included some of what worked and what didn't. Presented on how some of the robot was built.	Explained very little of the project process. Included very little of what worked and what didn't. Presented very little on how of the robot was built.	Did not explain the project process. Did not include what worked and what didn't. Did not present on how the robot was built.

5th Grade – Assigned Group Roles

	4	3	2	1
Participation	Usually shared work equally with building and programming, helped with the problem solving, and took notes for their notebook.	Often shared work equally with building and programming, helped with the problem solving, and took notes for their notebook.	Sometimes shared work equally with building and programming, helped with the problem solving, and took notes for their notebook.	Rarely shared work equally with building and programming, helped with the problem solving, and took notes for their notebook.
Project	Identified and chose a problem efficiently and effectively. Developed an appropriate solution. Built, programmed, and continued to test and improve the robot.	Identified and chose a problem. Developed a solution. Built, programmed, and tested and improved the robot.	Worked to identify and chose a problem, developed a solution, and build, program, and improve the robot.	Did not work to identify and chose a problem, developed a solution, and build, program, and improve the robot.
Presentation	Clearly explained what the problem was, the solution, and how it was decided. Gave thorough details on the robot. Clearly identified successes and failures.	Explained what the problem was, the solution, and how it was decided. Gave details on the robot. Identified successes and failures.	Explained some of what the problem was, the solution, and how it was decided. Gave some details on the robot. Identified some successes and failures.	Did not explain what the problem was, the solution, and how it was decided. Did not give details on the robot. Did not identify successes and failures.

5th Grade – Classroom Discussion

	4	3	2	1
Team Work	Usually worked together, listened to everyone's ideas, and shared work equally.	Often worked together, listened to everyone's ideas, and shared work equally.	Sometimes worked together, listened to everyone's ideas, and shared work equally.	Rarely worked together, listened to everyone's ideas, and shared work equally.
Project	Original solution. Robot performance was exemplary. Program performance was efficient. Tested and improved robotic solution.	Some original solution. Robot performance was good. Program performance was somewhat efficient. Tested and improved robotic solution some.	Very little original solution. Robot performance was acceptable. Program performance was a little efficient. Tested and improved robotic solution a little.	No original solution. Robot performance was not acceptable. Program performance was not efficient. Did not test and improve robotic solution.
Presentation	Usually maintained eye contact during presentation, used a clear voice. Clearly explained the process and how the group tested and improved the robot. Robot demonstration was successful.	Often maintained eye contact during presentation, used a clear voice. Explained the process and how the group tested and improved the robot. Robot demonstration was mostly successful.	Somewhat maintained eye contact during presentation, used a clear voice. Explained some of the process and how the group tested and improved the robot. Robot demonstration was somewhat successful.	Rarely maintained eye contact during presentation, used a clear voice. Did not explain the process and how the group tested and improved the robot. Robot demonstration was not successful.

5th Grade – Previous Instructional Practices

	4	3	2	1
Effort	Usually did not need much help from outside the group, listened to their group members, demonstrated perseverance, and listened to ideas from others with a good attitude.	Often did not need much help from outside the group, listened to their group members, demonstrated perseverance, and listened to ideas from others with a good attitude.	Sometimes did not need much help from outside the group, listened to their group members, demonstrated perseverance, and listened to ideas from others with a good attitude.	Rarely did not need much help from outside the group, listened to their group members, demonstrated perseverance, and listened to ideas from others with a good attitude.
Group Work	Usually shared work equally and took turns on building and programming.	Often shared work equally and took turns on building and programming.	Sometimes shared work equally and took turns on building and programming.	Rarely shared work equally and took turns on building and programming.
Project	Efficiently and effectively identified a problem and developed a solution, designed, built, and programed a robotic solution, and tested and improved the robot.	Identified a problem and developed a solution, designed, built, and programed a robotic solution, and tested and improved the robot.	Somewhat identified a problem and developed a solution, designed, built, and programed a robotic solution, and tested and improved the robot.	Did not identify a problem and developed a solution, design, build, and program a robotic solution, and test and improve the robot.
Presentation	Clearly explained how the group work was shared. Clearly explained the project process with details. Demonstrated an effective robotic solution.	Explained how the group work was shared. Explained the project process with some details. Demonstrated a robotic solution.	Explained some of how the group work was shared. Explained some of the project process with a few details. Demonstrated a robotic solution.	Did not explain how the group work was shared. Did not explain the project process with a details. Did not demonstrate a robotic solution.

APPENDIX B

Assigned Group Roles

Assigned Group Roles

Teacher Notes:

The roles consist of a planner/time manager, materials manager, project manager, and data manager. The time manager assists the group in monitoring the time they have available in comparison with the tasks to be accomplished for the class time and focuses on what needs to be done for that class and establish what should be accomplished in the next class. The materials manager is responsible for gathering and maintaining the materials needed for the project, the robotics kit and other miscellaneous items. The project manager is responsible for the big picture of the project and identifying tasks that may need to be accomplished for the final completion of the project. The data manager records any data and notes pertaining to the project. All the group members are welcome to collect their own notes in their Engineering Notebooks, but all the group members should include the notes of the data manager in their own notebooks for consistency. Since not all students can be programming or building on the robot at the same time, these activities will rotate through all four group members in a method established by the group before the project begins with the understanding that the time should be divided equally among the group members and everyone works on the programming or building within each class time.

Time Manager

Monitors time and tasks that need to be accomplished
Makes sure group focuses on most important issues and does not get off task
Conduct research
Assists in programming robot
Assists in building robot
Assists in design of robot
Record notes in your notebook

Materials Manager

Responsible for gathering and maintaining materials, robotic kit, etc.
Serves as the group spokesperson to the teacher or other groups
Conduct research
Assists in programming robot
Assists in building robot
Assists in design of robot
Records notes in your notebook

Project Manager

Identifies tasks that need to be accomplished for the class to complete project in the allocated time frame
Helps to make sure all the group members have jobs to do and all jobs are being completed
Moderates discussions
Conduct research
Assists in programming robot
Assists in building robot
Assists in design of robot
Records notes in your notebook

Data Manager

Records any data or notes for the project
Takes notes summarizing group discussions and decisions
Checks to make sure all the group members understand the ideas
Conducts research
Assists in programming robot
Assists in building robot
Assists in design of robot
Record notes in your notebook

APPENDIX C

Fowler Science Process Skills Assessment Pre-Test/Posttest Scoring Sheet

Fowler Science Process Skills Assessment
Pre-Test/Posttest Scoring Sheet

Name of Student ____________________________ School ________________________

Score one point on student paper for each item incorporated into design. Score two points if more than one sub-item is listed for a specific item.

Pre			Post
	plans to practice **SAFETY**		
	states **PROBLEM** or **QUESTION**		
	PREDICTS outcome or **HYPOTHESIZES**		
	lists more than **3 STEPS**		
	arranges steps in **SEQUENTIAL** order		
	lists **MATERIALS** needed		
	plans to **REPEAT TESTING** and tells reason		
	other items listed by student but not on list		
	DEFINES the terms of the experiment: "attracted to" "likes" "bees" "Diet Cola"	**DEFINES** the terms of the experiment: "attracted to" "likes" "earthworms" "light"	
	plans to **OBSERVE**		
	plans to **MEASURE**: (e.g., linear distance between bees, and/or cola, number of bees, time involved)	plans to **MEASURE**: (e.g., linear distance between worms, and/or light, number of worms, time involved, amount of light)	
	plans **DATA COLLECTION**: graph or table; note taking; labels		
	states plan for **INTERPRETING DATA**: comparing data; looking for patterns in data; in terms of definitions used; in terms of previously known information		
	states plan for making **CONCLUSION BASED ON DATA**: (e.g., time to notice drinks; bees may not be hungry; distances to sodas are equal; time involved for two samples is equal; temperature, light, wind, etc, are equal)	states plan for making **CONCLUSION BASED ON DATA**: (e.g., time to notice light; distances to light and shade are equal; time involved for two samples is equal; temperature, wind, etc, are equal)	
	plans to **CONTROL VARIABLES**: (e.g., bees not hungry; bees choose diet or regular soda; distances set equally; amounts of soda equal; number of bees tested are equal; temperature, light, wind, etc, are equal)	plans to **CONTROL VARIABLES**: (e.g., worms choose dark or light; distances set equally; number of worms tested are equal; time involved is equal; temperature, wind, etc., are equal)	

Pretest Score: ______ Name of rater: ____________ Date: _________

Post test score: ______ Name of rater: ____________ Date: _________

Source: Fowler, M. (1990) The diet cola test. Science Scope, 13(4), 32-34

DIRECTIONS FOR SCIENCE SKILLS PRETEST

1. Distribute one copy of the test to each child.

2. Read these directions out loud:
   Today you are going to take a test to see how well you can design an experiment.
   Look at your paper while I read the problem aloud:

(Form A) Are earthworms attracted to light? In other words, do earthworms Like light? Tell how you would test this question. Be as scientific as you can as you write about your test.
Write down the steps you would take to find out if earthworms like light.
You may begin.

(There is no time limit, but most will be through in 10-15 minutes)

Note: Students might ask if they may draw a picture of the experiment. If so, tell them they may, but they still need to explain their experimental design in words.

DIRECTIONS FOR SCIENCE SKILLS POSTTEST

3. Distribute one copy of the test to each child.

4. Read these directions out loud:
Today you are going to take a test to see how well you can design an experiment.
Look at your paper while I read the problem aloud:

(Form B) Are bees attracted to diet cola? In other words, do bees like diet? cola? Tell how you would test this question. Be as scientific as you can as you write about your test.
Write down the steps you would take to find out if bees like diet cola.
You may begin.

(There is no time limit, but most will be through in 10-15 minutes)

Note: Students might ask if they may draw a picture of the experiment. If so, tell them they may, but they still need to explain their experimental design in words.

APPENDIX D

Robotics Expo 2012 [Pre CEENbot] - Adapted 2015

Robotics Expo 2012 [Pre CEENbot] - Adapted 2015

Please circle best answer to each question.

Part I. Collaborative Problem Solving

We want to know how well the robotics project helps you to develop certain skills. Please respond to the items below in terms of how you contributed to your group in solving the robotics challenge and in preparing the group project and documentation.

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. I am able to brainstorm (come up with) a number of possible strategies to accomplish the robotics challenge.	5	4	3	2	1
2. I use a step by step process to solve problems.	5	4	3	2	1
3. I make a plan before I start to solve a problem.	5	4	3	2	1
4. I try new methods to solve a problem when one does not work.	5	4	3	2	1
5. I am able to explain my ideas and findings to my group.	5	4	3	2	1
6. I am comfortable presenting results produced by my group to the class.	5	4	3	2	1
7. I am able to interact professionally with the contest officials.	5	4	3	2	1
8. I am able to come up with creative ideas to help solve problems.	5	4	3	2	1
9. I carefully analyze a problem before I begin to develop a solution.	5	4	3	2	1
10. I am patient with my group members.	5	4	3	2	1
11. In the project I realize that it is often necessary to work with different people.	5	4	3	2	1
12. I like being part of a group that is trying to solve a problem.	5	4	3	2	1
13. I am able to help my group to accomplish the task within the allocated time frame.	5	4	3	2	1
14. Compromising with other group members is sometimes necessary to accomplish our goals.	5	4	3	2	1
15. I am able to share responsibility with my group members.	5	4	3	2	1
16. Whatever my role in the project I am able to follow through on the tasks needed to help to complete our group activity.	5	4	3	2	1
17. I am able to work with the group to help to prioritize, plan and manage the work to achieve the desired results.	5	4	3	2	1
18. I am an active participant in our group.	5	4	3	2	1
19. In order to solve a complex problem I break it down into small steps.	5	4	3	2	1
20. I am able to demonstrate leadership on selected tasks to help support my group.	5	4	3	2	1
21. Other group members are able to count on me to get something done.	5	4	3	2	1
22. When working in groups I ask my group members for help when I run into a problem or don't understand something.	5	4	3	2	1

Part II. Learning Motivation

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. It is important for me to learn how to conduct a scientific investigation.	5	4	3	2	1
2. It is important for me to learn about robotics.	5	4	3	2	1
3. It is important for me to learn how to use appropriate tools and techniques to gather, analyze and interpret data.	5	4	3	2	1
4. It is important for me to learn how to use mathematical formulas to help solve practical problems.	5	4	3	2	1
5. It is important for me to learn how to make accurate measurements to help solve mathematical problems.	5	4	3	2	1
6. It is important for me to be able to record measurements and calculations into tables and charts.	5	4	3	2	1
7. It is important for me to learn how to collect and interpret data to verify a prediction or hypothesis.	5	4	3	2	1
8. It is important for me to understand basic engineering concepts (e.g. design tradeoffs, speed, torque) related to building and moving a robot.	5	4	3	2	1
9. It is important for me to learn how to program a robot to carry out commands.	5	4	3	2	1
10. I like learning new technologies such as robotics.	5	4	3	2	1
11. I like using the scientific method to solve problems.	5	4	3	2	1
12. I like using mathematical formulas and calculations to solve problems.	5	4	3	2	1
13. I am confident that I can program a robot to move forward two wheel rotations (i.e. 720 degrees) and then stop.	5	4	3	2	1
14. I am certain that I can build a LEGO or similar robot by following design instructions.	5	4	3	2	1
15. I am certain that I can fix the software program for a robot that does not behave as expected.	5	4	3	2	1
16. I am confident that I can program a LEGO or similar robot to follow a black line using a light sensor.	5	4	3	2	1

Part III. How interested are you in each of the jobs below for possible future careers?

Job	Very Interested	Somewhat Interested	Neither Interested nor Uninterested	Somewhat Uninterested	Very Uninterested
1. Scientist	5	4	3	2	1
2. Engineer	5	4	3	2	1
3. Mathematician	5	4	3	2	1
4. Computer or Technology Specialist	5	4	3	2	1

APPENDIX E

Robotics Resources

The following websites contain free resources that can be useful for classroom teachers and students alike. There are other paid resources available that are not listed here and other resources that can be found with a search of the internet. These are the resources that have been used in the elementary engineering classroom by the teacher, the students, or both.

https://sites.google.com/site/gask3t/home - Mind-storms.com contains basic information about robotics in real world applications and for educational purposes. The site has both the NXT and EV3 resources.

http://stemrobotics.cs.pdx.edu/ - The site is designed for anyone interested in learning about or teaching robotics and includes curriculum and resources. Stemrobotics includes resources for EV3 and NXT.

http://robotsquare.com/ - Robotsquare has general information, building instructions, programming tutorials for RCS, NXT, and EV3 in addition to a variety of other resources.

http://www.stemcentric.com/ - STEMcentric is a resource for those involved with STEM education, either as a student or instructor. It is the home for the LEGO Robotics tutorials for the Mindstorms EV3, NXT and even the RCX.

http://www.legoengineering.com/ - The aim of this site is to inspire and support teachers to go beyond the basics in bringing LEGO-based engineering to all students. Resources are available for a variety of LEGO products including the RCX, NXT, and EV3.

http://ev3lessons.com/index.html#en-us – The ev3 Lesson site has resources only for the EV3 LEGO Mindstorm platform. However, some of the resources could be adapted for the other robotics platforms. Resources include lessons, building guides, and additional resources for First LEGO League teams.

http://www.nxtprograms.com/index.html - The nxtprograms website has projects, build and program instructions, listed based on the NXT kits. This can be a great resource because the retail and educational kits have different parts. Finding build instructions for the correct kit is made easy with the nxtprograms website.

http://tekbot.unl.edu/SPIRIT2/Assessments/ - resources from the University of Nebraska–Lincoln CEENBoT/TekBot Site. The site includes student and teacher resources.

APPENDIX F

IRB Approval Letter

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: September 01, 2015

To: Kellie Taylor cc: Youngkyung Baek

From: Social & Behavioral Insitutional Review Board (SB-IRB)
c/o Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval - Original - 104-SB15-152
Collaborative robotics, more than just working in groups: Effects of collaboration for all students on learning motivation, problem solving, and critical thinking in robotic activities

The Boise State University IRB has approved your protocol submission. Your protocol is in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Protocol Number:	**104-SB15-152**	Received:	8/18/2015	Review:	Expedited
Expires:	**8/31/2016**	Approved:	9/1/2015	Category:	7

Your approved protocol is effective until 8/31/2016. To remain open, your protocol must be renewed on an annual basis and cannot be renewed beyond 8/31/2018. For the activities to continue beyond 8/31/2018, a new protocol application must be submitted.

ORC will notify you of the protocol's upcoming expiration roughly 30 days prior to 8/31/2016. You, as the PI, have the primary responsibility to ensure any forms are submitted in a timely manner for the approved activities to continue. If the protocol is not renewed before 8/31/2016, the protocol will be closed. If you wish to continue the activities after the protocol is closed, you must submit a new protocol application for SB-IRB review and approval.

You must notify the SB-IRB of any additions or changes to your approved protocol using a Modification Form. The SB-IRB must review and approve the modifications before they can begin. When your activities are complete or discontinued, please submit a Final Report. An executive summary or other documents with the results of the research may be included.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Mary E. Pritchard

Dr. Mary Pritchard
Chair
Boise State University Social & Behavioral Insitutional Review Board