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RELATIONSHIP OF ROBOTIC IMPLEMENTATION ON CHANGES IN MIDDLE SCHOOL STUDENTS' BELIEFS AND INTEREST TOWARD SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

A Dissertation

Submitted to the School of Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Doctor of Education

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ABSTRACT

Title: Relationship of Robotic Implementation on Changes in Middle School Students' Beliefs and Interest toward Science, Technology, Engineering and Mathematics Author: Stephen H. Whitehead Dissertation Chair: Dr. Kelli Jo Kerry-Moran

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This quantitative study evaluates the impact of using robotics as a content organizer to teach a mathematic concept between math and technology education classes in a middle school of the students beliefs and interests toward STEM concepts.

The analysis was based upon pre and post belief and interest survey responses by the participating middle school students. Ten schools from Pennsylvania participated in the study over the spring semester of school in 2010. Twenty teachers (one mathematic and one technology education) worked in collaboration on the study which lasted between 2 and 6 weeks. A total of 107 students participated in the study.

The results were not statistically significant for all items but overall the differences were significant to support the hypothesis that the utilization of robotics as a content organizer could have a positive influence on middle school students' beliefs and interest toward STEM concepts.

iii

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There are many people who I must thank for sticking with me through this process: My parents for their unconditional love, support and constant encouragement. To my sons, Quinn, Zane and Trey, I hope this serves as encouragement for you to recognize that you can accomplish any dreams.

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iv

	Page
Signature Page	ii
Abstract	iii
Acknowledgement	iv
Table of Contents	V
List of Tables	vii
Chapter 1 – INTRODUCTION	1
Background	2
Purpose of Study	7
Research Questions	7
Theoretical Framework	8
Significance of Study	11
Limitations	12
Definition of Terms	12
Chapter 2 –LITERATURE REVIEW	14
Constructivism	14
Instructionism	18
Inquiry Based Learning	20
Cross-curricular Collaboration	23
Student Interest	26
Summary	28
Chapter 3 – METHODOLOGY	29
Research Content	29
Participants	29
Demographics	31
Study Design	33
Instrument	
Chapter 4 – RESULTS	40
Research Ouestion One	40
Research Question Two.	
Research Question Three	
Research Question Four	
Summary	58
Chapter 5 – SUMMARY CONCLUSIONS AND RECOMMENDATIONS	60
Summary	60
Objective One	61
Objective Two	62
Objective Three	63
Objective Four	65
Implications	0 4 64
Recommendations	65
Recommendations for Future Studies	66
Conclusion	67
References	67

TABLE OF CONTENTS

Appendix A Parent Consent Form	
Appendix B Student Consent Form	
Appendix C Technology, Engineering, Mathematics Survey	79

LIST OF TABLES

5
Table 1 Demographics of Participating Schools
Table 2 Technology Attitude Paired Sample t-Test Results 41
Table 3 Engineering Attitude Paired Sample t-Test Results
Table 4 Math Attitude Paired Sample t-Test Results
Table 5 Technology Interest Paired Sample t-Test Results 46
Table 6 Engineering Interest Paired Sample t-Test Results
Table 7 Math Interest Paired Sample t-Test Results
Table 8 Technology Interest Research Question Three Results 51
Table 9 Engineering Interest Research Question Three Results
Table 10 Math Interest Research Question Three Results 55
Table 11 Student Technology Interest from Collaboration
Research Question 3 Results

Page

Research Question	3 Results	58
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CHAPTER 1

INTRODUCTION

America's view of its education system is soured by the turmoil of the global economy. "There is no doubt that the national spirit at any moment colours the perspectives and behaviors of all the actors who shape, and are shaped by educational value" (Black & Atkin, 1996, p.14). In 2003 the U.S. Department of Labor reported that "60% of the new jobs being created then would require technological literacy while only 20% of the young people entering the job market actually have those required skills" (National Science Foundation, 2003, p.7). In 2000, more than 25 countries had a higher percentage of 24 year-olds with degrees in science and engineering than did the United States (NSF, 2004). These findings are quite disturbing as the global economy tightens and more science, technology, engineering and mathematics (STEM) centered careers transcend beyond the United States boundaries. All of these findings are helping to beat the drum for more STEM driven curriculum practices in education. STEM education is a focal point for policy makers, parents and business leaders of the United States of America.

Two major reports are at the center of these STEM concerns; *Rising Above the Gathering Storm* (2005) and *Energizing and Employing America for a Brighter Economic Future and American Competitiveness Initiative* (2005) by the National Academy of Sciences, National Academy of Engineering and the Institute of Medicine of the National Academies. These reports reveal the key elements of American prosperity in the 21st century and how science and technology played a critical role in that prosperity. The studies also evaluate how the United States is doing in science and technology currently through the educational system. In conclusion the researcher presents four recommendations and twenty actions to implement to maintain the

United States prosperity. This research concentrates on action A-3 found in the *10,000 Teachers*, *10 Million Minds and K-12 Science and Mathematics Education* recommendation:

Action A-3: Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass Advanced Placement (AP) and International Baccalaureate (IB) science and mathematics courses. Create opportunities and incentives for middle school and high school students to pursue advanced work in science and mathematics. (p. 6)

Background

Several years previous to the "*Gathering Storm*" report the American policy makers enacted federal legislation to produce students who successfully meet "proficiency" levels in reading, science and mathematics under the No Child Left Behind Act (NLCB) of 2001. One of the purposes of this act is to hold schools accountable for academic achievement, NCLB "requires stronger school accountability, more stringent qualifications for teachers, and an emphasis on programs and strategies with demonstrated effectiveness" (Reeves, 2003, p.1).

NCLB also specified that teachers of core academic subjects, such as mathematics and science, need to be highly-qualified. The definition of highly qualified is being state licensed and certified with demonstrated subject matter competency (Reeves, 2003). Even with these new governmental regulations in place nearly four out of ten teachers assigned to teach math in seventh through twelfth grade are not certified in mathematics. In science a quarter of all secondary teachers lack the proper certifications. Lacking highly-qualified science and mathematics teachers the majority of student experiences in these classes are centered on low level tasks which contribute to poor student attitudes and deficiencies in content and process understanding (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). In his

presidential address to the National Academy of Sciences Annual Meeting on April 27, 2009 President Barack Obama asked the scientific community to aid in the classrooms:

So I want to persuade you to spend time in the classroom, talking and showing young people what it is that your work can mean, and what it means to you. I want to encourage you to participate in programs to allow students to get a degree in science fields and a teaching certificate at the same time. I want us all to think about new and creative ways to engage young people in science and engineering, whether it's science festivals, robotics competitions, fairs that encourage young people to create and build and invent -- to be makers of things, not just consumers of things. (paragraph 74)

From grade eight on American students' attitudes toward STEM areas of study steadily decline based upon their experiences in classrooms where a disconnection between scientific/mathematics content and real-world application increase (Weinburgh, 2003). By infusing technology directly into math and science courses while melding science and mathematics concepts together we have a way to engage students in real world applications of these principles. Robotics is one technology that allows teachers to build STEM specific curriculum around technology that is engaging to both male and female students. Scientists, technologists, engineers and mathematicians use a process for problem solving. Often this designing process, or engineering process, implies steps will be followed for a successful resolution of the problem. Generally there are several steps in the process: identification of the problem, information gathering related to the problem and possible solutions, inventory of material available to solve the problem, development of possible solutions, selection of the best solution, prototype development and evaluation of prototype and refinement of the solution.

Allowing the students to utilize engineering processes as part of the course requirements enlightens the students to the daily practices of engineers and technologists.

The National Council of Teachers of Mathematics (NCTM) is seeking ways to improve education so that meaningful; context rich learning environments are created for students (Harris, et al., 2001). Students involved in problem based curricula demonstrated increased higher order thinking skills and more positive attitudes toward the subject matter (Harris, Marcus, McLaren, & Fey 2001). Design Based Learning (DBL) is a well thought out design-project that teachers use to extend students knowledge of science and math as the student develops a technological solution using limited resources (Schunn, 2009).

Design based learning allows the students to study subjects that are created from the students' environment. By creating authentic activities, activities that deal with real world situations, the students are granted the opportunity to develop thinking skills as well as an indepth knowledge of the content area. "It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other." (American Association for the Advancement of Science, 1993, p.3).

Johnson (2002) states that robotics offer an educational advantage, "although simulation of physical systems can be very realistic, the pedagogic value of robotics lies in making them work." Robotics allows students to be observers, interact and construct their own knowledge that is relevant to a specific area or task. It has been argued in other studies that robotics support constructivism by allowing students to generalize from their experiences and bridge experiences and curriculum (Jadud, 2000).

Implementing robotics with a DBL activity enriches the experience and strengthens the connection between content and real world applications for the students. Through the completion of hands-on activities students' develop a meaningful understanding as an active process with all the advantages of active learning. (Dopplet, Mehalik, Schunn, Silk & Krysinski, 2008).

Robotics is defined by the Carnegie Mellon's National Robotic Engineer Center as the study of the technology associated with the design, fabrication, theory, and application of robots. In 2007 six million five hundred thousand robots were in operation in the world. (IFR Statistic department), robotic manufacturers predict that by 2011, eighteen million robots will populate the world. That is an increase of nearly three hundred percent in four years. Capitalizing on robotics and the competiveness of students and schools the FIRST (For the Inspiration and Recognition of Science and Technology) Lego League (FLL) is for students to discover the value of education and careers in science, technology and engineering through the excitement of sports with a science and technology twist. The student teams, working with adult mentors (engineers, teachers, mathematicians and scientists), must determine a winning strategy over a six week period. The students build, and test their robots to meet the season's engineering challenge. In spring of 2010 the game was BREAKAWAY. BREAKAWAY consists of two alliances of three teams, competing on a 27 by 54 foot playing surface designed with multiple raised areas. The primary way for teams to earn points was by collecting soccer balls in goals. Bonus points were awarded for each robot parked off of the playing surface, on a raised platform, at the end of the match. Students learned about building alliances and professionalism through participation in the challenge. FLL challenges students of all ages starting with Junior FLL for ages 6-8, FLL ages 9-14 and First Tech Challenge and Robotics competition for high school students (ages 15-18). In 1992 twenty eight teams entered the first FLL challenge in 2008 one thousand five hundred

and one teams competed, that translates into 38,000 high school students. Creating excitement in the classroom that is equivalent to that generated in these types of events will better engage students to follow STEM career and educational paths.

The goal of this study is to improve middle school students' attitudes toward three of the STEM areas, technology, engineering and mathematics, by implementing robotics in the classroom to improve the educational experience while also increasing the classroom inquiry level. The researcher defines inquiry as "the scientific process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interest" (Llewellyn, 2004). The research will focus on the areas of technology, engineering and mathematics. Mathematics was selected because in the Pennsylvania middle school curriculum the content is easily adaptable to apply with robotic equipment. Whereas the Pennsylvania science curriculum is less appropriate for robotics since the core material is centered among life science, environmental science and earth and space science.

There are several programs available for high school students to build an excitement towards STEM career and educational paths. As well as FLL, Battle Bots, and VEX competition to name a few are designed to engage students to look deeper at engineering based careers. While this goal is admirable a major drawback in delaying until high school to sway students over to the engineering career path is that the students may be inadequately prepared for success in the college courses required for STEM careers. The high school students who are excited to pursue a career in STEM related fields may find themselves lacking the basic mathematics and science skills to be successful at the post-secondary level. These students will be required to build basic mathematics and science skills at the college level. This in several cases delays graduation as they are forced to complete courses that are available to them in high school.

Therefore we need to engage the students in the middle schools so they will be better prepared for a successful transition to college in their pursuit of STEM careers. The stronger the students' foundation is in science, technology, engineering and mathematics the greater the success rate in growing the pool of students from the United States seeking degrees in these fields.

Purpose of Study

The purpose of this study is to demonstrate how robotic activities designed around specific math content can influence Pennsylvania middle school students STEM interests and beliefs as a function of inquiry based learning. The researcher is the primary investigator for the National Science Foundation "Robotic Corridor" grant subcontracted to California University of Pennsylvania. One of the objectives of the grant is to improve the quality of students pursuing Technology Education, Engineering Technology, and Engineering undergraduate degrees. This initiative prepares future scientists and engineers by integrating rigorous math and science into K-12 STEM education. The robotic corridor is centered in Pennsylvania which is a key reason for the study being completed in Pennsylvania.

The researcher's decision to concentrate on the attitudes of middle school students toward STEM is directly related to the documented decline in students' interest toward STEM from middle school forward. The researcher believes robotics will hinder this negative trend by building the students' level of inquiry towards these (STEM) subjects.

This study determines if a robotic centered activity affects both classroom inquiry level and middle school students STEM interest and beliefs.

Research Questions

The research questions reflect the concern for improving students' beliefs and interest toward STEM concepts. The need for additional research in the employment of robotics in the

activity to foster inquiry in the classroom is also addressed in the research questions. The following are the research questions the study is based upon:

- 1. What are the significant effects robotic centered activities significantly have in middle school students' STEM attitudes?
- 2. What are the significant effects robotic centered activities have in middle school students' STEM interests?
- 3. What is the significant relationship that exists between robotic centered activities and classroom inquiry levels?
- 4. What is the significant relationship that exists between classroom collaboration and middle school students' STEM interests and attitude changes?

Theoretical Framework

The study intends to use robotics as the stimulus for promoting positive STEM images, enhancing the students' STEM knowledge, STEM career interests and decisions of the participants to pursue these careers. The robotics will be used to develop meaningful learning through hands-on investigative activities in cooperative middle school classrooms (science, technology, engineering and mathematics). Constructivism is the underlying theory in most science, engineering and technology classes because it highlights students' prior knowledge of important concepts; therefore; it will be employed to create a student centered learning environment.

The constructs of students' STEM attitudes and interests combined with the principles of constructivism are significant components for promoting STEM literacy. Having an interest in something is a learned response of liking or preferring (Koballa, 1988). Science attitude research shows that an understanding and interest in science concerns may be viewed as fundamental for

scientific cognition and awareness (Siegel & Ranney 2003). Interest is embedded with attitude in this study. The significance of the science attitude research findings is extended to the TEM concepts based upon the relationship between interest and attitude.

One of the main theorists credited with establishing constructivist learning theory is Lev Vygotsky. The major theme of Vygotsky's theoretical framework is that social interaction plays a fundamental role in the development of cognition. Vygotsky states:

Every function in the child's cultural development appears twice; first, on the social level and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory and to the formation of concepts. All the higher functions originate as actual relationships between individuals.(p. 75)

Vygotsky asserted that full cognitive development requires social interaction. Bruner's major theme that learning is an active process in which learners construct new ideas or concepts based upon their past knowledge builds from Vvgotsky's work. The learner selects and transforms information to construct a hypothesis and make decisions, relying on a cognitive structure to do so. Cognitive structure provides meaning and organization to experiences and allows the individual to go beyond the information given. Bruner believed that the instructor and student should engage in an active dialog. This belief's findings are in socratic learning practices, which is the method of instruction where questions and answers are used to elicit from students truths the instructor considers to be implicitly known by all everyone. The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding. *Constructivist Theory (J. Bruner)* Retrieved April 11, 2009, from http://tip.psychology.org/bruner.html.

The constructivist learning theory suggests a number of points about teaching and learning (Bencze, 2006): Learners approach topics with pre-conceived notions about what the teacher wants them to learn; Learners current thoughts may contradict the teachers; Learners are reluctant to change their thoughts; Learners need to test ideas through relevant activities; Learners need other people to help change their idea; Learners need to see through different lenses and Learners have the right to determine their own beliefs.

In reviewing the first point, learning from our environment is an active process, so consider the environment in which the students have been submerged when understanding their constructed knowledge. This constructed knowledge is what the students arrive with in classrooms. Today's children have been altered tremendously by the technological revolution, but that same technology has yet to make a significant impact in our educational system (Ferguson, 2001).

Creating activities that are relevant and allow the learner the opportunity to view the topic from several sides is required. With the use of the constructivism philosophy we should be able to integrate robotic technology seamlessly into activities. According to Bruner, constructivism is a teacher-facilitated process that places students at the center of active learning, rather than in a passive role. The students actually invent their own ideas. This (robotic) technology can improve the students' ability to solve problems, communicate, work as a team, acquire and evaluate information, think creatively and make decisions. (Dwyer, Ringstaff, & Sandholtz, 1990)

Researchers and educators are linking constructivism and learning technology. There is strong support for the principles of constructivist philosophy in computer-based learning environments. Current interactive multimedia technologies have the potential to represent ideas

in almost any form so students view the resources, creating their own understanding of the information encountered. "Learning should not only take us somewhere; it should allow us later to go further more easily" (Bruner, 1969). In the constructivist framework cognitive tools allow the learner to organize, restructure and represent what they know.

Design based learning (DBL) easily fits within the constructivist framework by allowing the student to construct knowledge as a result of learning according to their own style. DBL creates an active learning environment in which the teachers transition from the "sage on the stage" to a guide for the students. There are several advantages to DBL (Dopplet, Mehalik, Schunn, Silk, Krysinski, 2008): Increased student motivation due to the obvious connection of knowledge gained and real life situations; Active process therefore incorporating all the elements of active learning and Collaborative learning through team based activities.

The application of robotics as a content organizer for STEM activities within a DBL project allows the students to benefit from these previously mentioned constructivist advantages.

Significance of Study

There is very limited research on the effects of robotics as the content organizer on middle school students' interest and beliefs about STEM subjects. In addition the pool of research on inquiry based learning and students' STEM attitudes using quantitative research is shallow. Therefore a need has been established for studies identifying characteristic that effect attitude changes quantified with robotics and inquiry based learning. This research is expecting to reveal specific characteristics of inquiry-based learning with robotics and their connection to improved student attitudes toward STEM concepts.

Limitations

The study acknowledges some limitations that may impact the internal validity of the research. The researcher prior to implementation of the study has served as the trainer for several teacher professional development sessions on strategies for utilizing robotics for STEM concepts in the classroom, robotic outreach activities at the Carnegie Science Center, VEX robotic competitions and South Western BOTS IQ competition. Researcher bias is acknowledged because of the close relationship that may have formed between the researcher, teachers and students, whom participated in these events.

In addition the study involves a localized, voluntary sample: therefore caution should be taken in generalizing results to a broader population. The participants were contacted through the mail and by electronic communications from a data base of schools (teachers) whom have shown consistent interest in developing and employing a robotic curriculum in their schools. Therefore the participants may have been exposed to other activities or educational experiences that may have influenced the participants' attitudes and beliefs toward STEM concepts.

Definition of Terms

Attitude – Positive or negative way in which an individual feels toward Science, Technology, Engineering and Mathematics issues such as, basic concepts, skills and careers.

Constructivism - A teacher-facilitated process that places students at the center of active learning, rather than in a passive role. The students actually invent their own ideas.

- *Design Based Learning (DBL)* A well thought out design-project that teachers use to extend students knowledge of science and math as the student develops a technological solution using limited resources (Schunn, 2009).
- *Inquiry Learning* A student centered, active learning approach focused on questioning, critical thinking, and problem solving.
- *Learner Centered* An environment that pays attention to the development of knowledge, skills, attitudes and beliefs that learners bring to the environment (Voss & Ellis, 2002).
- *Learning* The process of acquiring ideas, knowledge or applying prior knowledge and experiences to new information to promote accurate conceptual development (Anderson, Lucas, & Ginnis, 2003).
- *Meaningful Learning* A view of learning as knowledge construction in which students seek to make sense of their experiences.
- *Scaffolding* A teaching strategy that provides support mechanisms to facilitate a student's ability to build on prior knowledge and internalize new information (Bransford, Brown & Cocking, 2000).

CHAPTER 2

LITERATURE REVIEW

This chapter represents a review of literature significant to the study relating to: (a) constructivism as the common learning theory applied with robotics, (b) the benefits of inquiry learning, (c) the benefit of cross curricular teacher collaboration, (d) the issues of student interest and beliefs on educational outcome.

The chapter begins with an examination of the roots of constructivism through the progression of its development as the application of choice when employing educational robots. An examination of the differences between constructivism and instructionism follows, as well as an exploration of the history behind, and similarities and differences between, Design Based Learning and Inquiry Based Learning. The chapter closes with an appraisal of cross curricular collaboration in the current educational environment while closing with the importance of the students' interests and beliefs in education.

Constructivism

Constructivism is the learning theory commonly associated with robotics so it is important to understand its epistemological roots. Within the epistemology, there are two perspectives; objective and subjective (von Glaserfelt, 1995a). The objective perspective maintains that knowledge is absolute and separate from the learner. Therefore, knowledge is assumed to exist separate and independent of the knower; knowledge is considered true only if it correctly reflects that independent external world (Gross, Levitt, & Lewis, 1996).

The subjective perspective is opposite of the objective perspective. The subjective viewpoint maintains that knowledge is constructed based upon personal experiences and their

interaction with the environment. Reality "is made up of the network of things and relationships that we rely on in our living, and on which, we believe, others rely on, too" (von Glasersfeld, 1995a, p. 7). Constructivism is the educational application of the subjective perspective.

Constructivism is often related to Jean Piaget in what is defined as "cognitive constructivism." This theory maintains that when information is simply given directly to an individual, instantaneous understanding and the ability to use the information does not occur.

Individuals "construct" their knowledge through personal experiences. These personal experiences allow us to create what Piaget identified as schemas. Schema is a cognitive framework or concept that helps organize and interpret information. These schemas are altered through two complimentary processes: assimilation and accommodation.

Assimilation involves the interpretation of events in terms of existing cognitive structure. An example is a file cabinet drawer filled with files designated for specific information. If we encounter new information which fits into one of the designated folders we can easily assimilate it to fit our understanding by filing the information in the designated folder. Accommodation refers to changing the cognitive structure to make sense of the environment. The internal world has to accommodate itself to the evidence with which it is confronted and thus adapt to it, which can be a more difficult and painful process (Atherton, 2010). In the file cabinet drawer scenario stated previously, an example of accommodation would be adding a new folder to "accommodate" this new information.

Applying Piaget's theory to teaching and learning has two key principles: learning is an active process and learning should be authentic.

"The fundamental basis of learning was discovery. To understand is to discover, or reconstruct by rediscovery, and such conditions must be compiled with if in the future

individuals are to be formed who are capable of production and creativity and not simply repetition. To summarize, the key finding from Piaget is that students' understandings are constructed through interactions with the world around them" (SEDL, 1995, Introduction, para 4).

From Piaget's "cognitive constructivism" theory Vygotsky and Bruner developed "social constructivism", which place a greater emphasis on language and interaction with others.

The major theme of Vygotsky's theoretical framework is that social interaction plays a fundamental role in the development of cognition. Vygotsky states, "Every function in the child's cultural development appears twice; first, on the social level and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory and to the formation of concepts. All the higher functions originate as actual relationships between individuals" (Vygosky, 1978, pg 54).

Vygotsky believed that the potential for cognitive development depended on the zone of proximal development (ZPD). Zone of proximal development is defined as a level of development attained when children engage in social behavior. Vygotsky believed full development of ZPD required full social interaction.

Where Vygotsky believed that full cognitive development requires social interaction, Bruner's major theme is that learning is an active process in which learners construct new ideas or concepts based upon their prior knowledge. The learner selects and transforms information to construct a hypothesis and make decisions, relying on a cognitive structure to do so. Cognitive structure provides meaning and organization to experiences and allows the individual to go beyond the information given. Bruner believed that the instructor and student should engage in

an active dialog (Socratic learning). The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding. *Constructivist Theory (J. Bruner)* Retrieved April 11, 2006, from http://tip.psychology.org/bruner.html

In a 1987 proposal to the National Science Foundation, Seymour Papert defined a theory of learning called "constructionism" based upon "constructivism" which he defined as:

The word constructionism is a mnemonic for two aspects of the theory of science education underlying this project. From constructivist theories of psychology we take a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product. Retrieved April 11, 2006 from http://nsf.gov/awardsearch/showAward.do?AwardNumber=8751190, abstract paragraph

Papert's theory stresses the importance of self directed learning. The learners themselves develop and explore the connections that best suit what they wish to learn. The learner develops genuine ideas that allow them the opportunity to communicate these ideas with others. This in itself correlates well with the social constructivism research.

The obvious question then is how "constructionism" differs from "constructivism"? The key difference is in the type of initiative the learner takes in designing the objects that aid in learning. In Papert's book "Constructionism" he writes "vivent les differences" which mean "long live the differences". The major point he desires to impress upon the reader is that everyone does not learn in the same way and as educators we should embrace these differences.

Even if a majority of students were able to identify the "best" solution to a problem, other students have the ability, and probable preference to successfully solve the problem their way.

In constructionism the use of new technologies is employed to create "learning-rich" activities. Papert endeavors to develop "cybernetic" activities that will become part of the lives of young children. Cybernetic refers to "constructed forms of artificial life and mobile models capable of seeking environmental conditions such as light or heat or of following or avoiding one another" (Papert, 1991, pg 12). Papert's hypothesis of creating learning-rich activities centers on the development of a "cybernetic" device. The LEGO NXT Mindstorm robot (NXT) is the fulfillment of that device. The NXT and the supplementary software is the tangent piece, the new technology, which is an example of the creation of learning-rich environments in the constructionism application.

Instructionism

Papert believes the employment of the Lego NXT in the classroom allows for a constructionism approach to benefit instruction and student learning. However, in recent years there has been a shift in education to an "instructionism" approach within the classroom. Instructionism is defined as the educational practices that are teacher-focused, skill-based, product-oriented, non-interactive, and highly prescribed (Johnson, 2005). The most common classroom application of instructionism is direct instruction. The most common form of direct instruction is lecture. The teacher follows a sequence of events, stating the objective, reviewing the necessary skills for mastery of the content, presenting new information, and questioning students. Instructionism is the educational application of objectivism.

A teacher exclusively employing direct instruction (instructionism) may need to respond to a student's question of "Why do I need to know this?" The student is expressing that the

content being presented has no relevance to them. If the teacher is unable to show a real world application of the content, the students respond by memorizing the information to be recited at a later date for success on an assessment. This type of knowledge is referred to as "inert knowledge" – knowledge that cannot be applied to real problems or situations (Grabinger & Dunlap, 1998).

The argument against instructionism is that it automates student and teacher performance and negates true learning. Direct instruction is based on the concept that the goal of instruction is to identify and teach subskills. All skills and concepts required to be proficient are broken into subskills or small component skills that are taught in isolation (Kameenui & Carnine, 1998). Each subskill is taught in repetition until students achieve a level of proficiency in the eyes of the teacher or administrators. Classes are teacher-centered, skill-based and non-interactive.

There have been several educational studies attempting to show which method (constructinism vs. instructionism) is best suited for the classroom. With the constructivist approach and the use of robotic technology the realization of meaningful learning may occur in the classroom. Robotic technology supports the process of joint knowledge development; according to students' own interests, along with project based challenges that encourage students to "learn to learn"; student groups are seeking solutions to real world problems, which are based on a technology-based framework used to engage students' curiosity and initiate motivation, leading so to critical and analytical thinking; all of these items are examples of constructivism (Alimisis, Moro, Arlegui, Pina, Frangou, and Papanikolaou, 2007). "The lesson of constructivism is that meanings are constructed by pupils for themselves "(Black & Atkin, 1996, p. 46).

While neither constructivism nor instructionism has been confirmed to be superior when robotics are used in the classroom, the research suggests that a constructivist approach is most beneficial. Constructivism transfers some of the responsibility of learning to the student which empowers the student to have ownership over not only the project outcome but the ideas gained from the exercise.

Inquiry Based Learning

With the history and definition of constructivism stated, benefits of inquiry based learning will now be examined. To address this issue one must start by defining learning. The American Psychological Society states that learning is the acquisition of skill or knowledge. This is a generic definition that showcases how learning is often misinterpreted with the product of learning. "Learning itself is an implicit process or series of processes. The observable change is a product" (Lachman, 1997 p. 44). Lachman asserted that a comprehensive definition of learning would incorporate the following key points (1997): incorporate the stimulus-response relationship, distinguish learning from other phenomena, consider learning a process not be confused with the products of learning, favor more objective learning and be applicable at every level of human development. Lachman's definition of learning is "the process by which a relatively stable modification in stimulus-response relations is developed as a consequence of functional environmental interaction via the senses" p. 36.

The teaching technique of inquiry originated from "scientific inquiry", a way of thought guided by specific assumptions and principles. Inquiry allows the student to learn about the associations between elements and consequences instead of simply learning facts. A study of high school science textbooks by Tafoya, Sunai and Knecht (1980, p. 44) identified four levels of inquiry activities: confirmation, structured-inquiry, guided-inquiry, and open-inquiry:

Confirmation – A concept or principle is presented and the student performs some exercise to confirm it. The procedure is well defined for the student to follow and the outcome is also known by the student, *Structured Inquiry* – The student is presented with procedures for solving a problem but does not know the solution/answer, *Guided Inquiry* – The student is presented with a problem without any procedure for solution or knowledge of the desired outcome and *Open Inquiry* – The student generates the problem, procedure and solution independently.

In 1996, the National Research Council endeavored to standardize the definition of inquiry-based learning in educational terms:

Observing; posing questions; examining books and other sources of information to see what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (p. 23).

An effort to reinforce the definition led to the National Research Council issuing the five essential elements of classroom inquiry for all grade levels in 2000.

- 1. Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- 5. Learners communicate and justify their proposed explanations (NRC, 2000, p. 25).

Project based learning (PBL) and Inquiry based learning (IBL) is hard to distinguish between and therefore is often used as synonyms in research articles. The origins of PBL and IBL are the major area of difference between these learning approaches. PBL has its origins in medical education and is based upon research on medical expertise that emphasized a hypothetical-deductive reasoning process (Barrows & Tamblyn, 1980). IBL has its origins in the practices of scientific inquiry and places a heavy emphasis on posing questions, gathering and analyzing data, and constructing evidence-based arguments (Krajcik & Blumenfeld, 2006). PBL is centered on the educational goal of solving a problem. IBL is focused on gaining knowledge as the educational goal. An important technique utilized for instructors in both PBL and IBL is instructional scaffolding which aids students' learning.

Instructional scaffolding is employed when new concepts or skills are introduced to students. The scaffolding consists of support material such as resources or a compelling task. As students become more adept with the content, the instructor gradually removes the scaffolding. An example of scaffolding at work in the classroom would be the instructor assigning a research problem, dividing the students into small groups to analyze the problem, determine solutions, and evaluate the process collectively. The teacher could supply "soft" or "hard" scaffolding to the students at this time. "Soft" scaffolding would be demonstrated by the instructors circulating among the groups and conversing with the students (Simon and Klein, 2007). An example of "hard" scaffolding would be handouts showing websites that would aid the students in the exploration of the problem. "Hard" scaffolding must be planned in advance by the instructor for the activity. The burden of scaffolding falls upon the instructor to determine the content that requires scaffolding, when to implement it and when to remove it. Scaffolding allows the

students to become more familiar with the content, the problem solving approach, and to gain the experience of applying the content in a specific manner.

When the teacher successful merges the Inquiry Based Learning approach with scaffolding a key benefit is that a portion of the responsibility of learning transfers from the teacher to the students. Even superior quality teachers cannot ensure that learning will occur in their classroom. The instruction presented is only to be a stimulus for students who are open and receptive to it. Many teachers will bemoan how the students are constantly asking "Why do we need to learn this?" This question in itself shows that students do not see a direct connection with the content being taught and their life.

With the introduction of inquiry based learning, the teacher is creating a student-centered classroom experience where the students learn through self discovery; the teacher acts as a knowledge guide. The students are impressed with a desire to solve a problem that is based on a real world situation. Inquiry Based Learning is a perfect fit with four principles that have been identified as beneficial in aiding early engineering learners (Schunn, 2009): engage students in solving significant design problems from the beginning, make visible models to support the design task, interactive design and redesign are better than single design cycles, provide sufficient time for exposure to material.

Applying these principles in the formation of a "design challenge" assures students the opportunity to think through the design challenge, and correlate the relationship between sciences, engineering and mathematics concepts. This approach utilizes a guided inquiry teaching approach where students are presented with a challenge and then create procedures to develop a successful solution.

Cross-Curricular Collaboration

A cross-disciplinary approach attempts to encourage students to increase their understanding by working within each discipline to focus on concepts that are shared. This instructional approach constructs a bridge which allows the student to see the natural connection between specific disciplines. In the case of this research, the students will see a clear connection between technology, engineering and mathematics.

In the current high-stakes assessment education era, many schools require teachers from different disciplines to develop projects that overlap their areas. Research supports the belief that projects that connect disciplines allow students to learn more about each discipline involved in the project.

The Standards for Technology Literacy Content speaks directly to the correlation between Technology Education and Mathematics. In 2000, The International Technology Educational Association released content standards.

"Scientific and mathematical knowledge and principles influence the design, production, and operation of technological systems. Science concepts, such as Ohm's Law, aerodynamic principles, and the periodic table of elements, are used in the development of new material and design. Mathematical concepts, such as the use of measurement, symbol, estimation, accuracy, and the idea of scaling and proportions are key to developing a product or system and being able to communicate design dimensions and proper function" (p. 60).

"Fundamental mathematics is a core subject that is essential to further studies in other content areas such as the technologies, engineering and sciences" (Litowitz, 2009). Technology

classrooms have incorporated mathematics and science in the curriculum from their initial development. The students learn these (mathematical) concepts in real world applications in the technology classroom.

In an effort to improve student scores in math on the standardized state test, Technology Education teachers are being required to assist the Mathematics department by teaching math concepts during their contact time with students. The negative aspect of this situation is that both the mathematics and technology teacher are working independently of each other. The math teacher maintains the status quo of their curriculum and the technology teacher is simply told to include math in their activities. This leads to a detachment for the students between concepts being taught in the math classroom and the technology classroom.

In example, the technology teacher may be starting a lesson that requires a specific math concept that may not have been formally presented in the math session. This leads to frustration of not only the students but also the teachers. Even when the technology teacher develops an activity that targets a mathematics problem, there is no guarantee that the students will learn math (Silk, Higashi, Shoop & Schunn, 2010). True collaboration occurs when both sides are represented in the development of the project. By scheduling time for the teachers from different disciplines to plan together we assure the opportunity of collaboration exists.

An assessment of the project should address the following questions (Silk, et al, 2010):

- 1. Are students interested to see the problem through?
- 2. Do they talk about the math that you are trying to teach them?
- 3. Is the math simple, numerical equations obtained by guess-check, or do the students develop general equations?
- 4. Do students provide explanations about the math in their solutions?

When the design based learning activity is developed, it makes sense to construct the activity to address these four questions, as in backward design techniques for curriculum development. The instructor begins by identifying the key concepts (mathematics, science, engineering or technology) that will be learned by the students and then develops the assessments to verify that learning occurred over the activity. From there the instructor designates the steps that will best aid the students in the development of the skills required to successfully complete the activity. When the key concepts match two curriculums (mathematics / technology education), both teachers benefit by being involved in the developmental process. This is the step that is most commonly overlooked in collaboration. Both teachers feel that their area is of the most importance and expect the other teacher to help out but do not describe or review how that will happen with the students.

Student Interest

To have successful curriculum integration, it is essential to establish the importance of collaboration not only to the students but also the teachers. To focus on student-centered learning (constructivism) the curriculum must include: learning has more meaning if based upon experience, learning is greatly aided when the students have a real-life need to know, students (and teacher) can answer "Why do I need to know this"? and learning should be tied directly to a practical application.

Therefore, successful learning occurs when the content being delivered is expressed as relevant information to the students (Callison, Bundy & Thomes, 2005). The main objective of collaboration is the capacity of the participants to consistently communicate respective goals and objectives throughout the activity. Each participant must be aware of the coordinated outcome to increase the success of learning for students.

There is a direct connection between students learning relevant content and their motivation (attitude) toward the content area. The learner's motivation is key in influencing their academic engagement and achievement. If one aspires to improve students' attitudes then the natural conclusion is that one must make the curriculum relevant to the students. Through collaboration between STEM content areas and activities that are relevant, students are able to observe the natural correlations between STEM areas and the everyday applications.

A study by Singh, Granville and Dika (2002) illustrated that middle school ($5^{th} - 8^{th}$ grade) is a critical period for students in respect to mathematics and science achievements. This group was established as having the highest drop in STEM interest. An examination of the factors causing this drop is critical as these years are when students consider future career and academic pathways (Singh, et al., 2002).

The Third International Mathematics and Science Study (TIMMS) was a comprehensive international assessment administered to 8th graders evaluating achievement in science and mathematics in 1995 and repeated in 1999 (given to students who where in 4th grade during the 1995 assessment). The assessment determined that the average United States student was below the average of the same level of students in 23 countries (Schmidt, 2000). Further evaluation of the data suggests that U.S. students' standing in mathematics and science declines as they progress through school (Forgione, 1998). The conclusion to these findings is that student's attitudes toward STEM have a direct relationship upon not only academic success but career aspirations.

Research states that students respond to structured activities, relevant experiences with positive attitudes and personal investment in their educational goals. With the implementation of well developed curriculum collaboration, design based learning activities that blend the edges of

the content areas (for the students), and the utilization of student-centered learning, all students are given the opportunity for an enriched educational experience.

Summary

This chapter examines constructionism from its' epistemological roots to its' growth as the preferred educational method employed with robotic technology. In conjunction with the history of constructivism an examination of instructionism was presented for a deeper understanding of the differences between these two educational methods. This was followed with the exploration of the development of Design Based Learning and Inquiry Based Learning and their similarities. The chapter ended with an appraisal of cross curricular collaboration in the current educational environment.

In conclusion the natural technique for employment with educational robots is clearly constructivism from the research reviewed. In addition the research shows the benefits of exploiting Design Based Learning (or Inquiry Based Learning) techniques, depending on the desired learning outcome, in conjunction with cross curricular collaboration to increase student engagement in science, technology, engineering and mathematics courses.
CHAPTER 3

METHODOLOGY

Research Context

The literature review illustrates that students' attitudes toward STEM related careers and academics are significantly influenced during the middle school years. The data implies that student' attitudes toward STEM academic courses decline during these school years and continue to decline as students progress through the high school years. This study investigates if the use of robotics, along with collaboration between Mathematics and Technology Education teachers, can aid in curtailing this negative tide.

Participants

To recruit participants for the study, the researcher communicated with teachers and administrators through electronic communication. The Technology educators were identified by their participation in robotic education courses available through Carnegie Mellon's National Robotic Education Center (NREC) and professional development (based around robotic curriculum) sessions offered at California University of Pennsylvania. The teachers who participated in these training sessions received a phone call inviting them to participate along with an electronic communication (email) stating details of the study. The email was converted to an Adobe Portable Document (PDF) and added to the homepage of the Technology Educational Journal of Pennsylvania (TEAP) as an advertisement. Lastly, there was a virtual meeting held with interested teachers using Go to Meeting technology to discuss any questions or concerns that teachers (or district administrators) may have had before the schools were asked to commit to participating in the study.

With the financial support of a grant, the researcher was able to provide the following items to aid in recruitment of teachers to participate in the study:

Stipend of \$750 for each teacher participating in the study

The money was paid upon completion of the study at the cooperating school to the faculty members. Each faculty member received a payment of \$750.

Previously under the grant, Technology Education Teachers were offered \$1,500 to implement a robotic course in their school district. The teachers were paid \$500 when the training was completed and the balance (\$1,000) after the first robotic course was completed in the academic year. With no additional money being supplied from the NSF for this grant, the researcher was forced to split the amount of monetary incentive between the participating teachers in the study.

Teachers were required to attend a training session covering an introduction to the robotic kits that were available for the study, along with the development of a design-based learning activity that fit the current school curriculum.

After utilizing the recruitment techniques, twenty-three schools confirmed interest in participating in the study, however, there was only funding to support ten schools. Therefore, the researcher was required to reduce the field of twenty-three to ten accepting the first ten schools who agreed to participate in the study. Of the ten schools who committed to participate in the study nine successfully completed the research. One school withdrew from the study due to one

1 Lego NXT Mindstorm Educational Robotic Kit (per participating teacher)

of the participating teachers being unable to fulfill the study requirements. All of the schools participating in the study were located in Pennsylvania.

The participating teachers sent an informational letters home to their students' parents to seek participant permission along with explaining to the students the details of the study. A total of 107 students, 71 males and 36 females, from the nine middle schools agreed to participate in the study. Of all the students who were offered to participate in the study 75 % agree to participate in the study. Students were offered the opportunity to participate as long as they met the following requirements:

Where assigned to the classes for the participating Mathematics and Technology

Educator classes for the spring 2010 semester.

Students agreed to participate in the study. Students who declined the opportunity to participate in the study were allowed to complete the collaborative activity but did not need to complete the pre and post survey.

The students and their guardians demonstrated their agreement to participate by signing a consent form (Appendix A & B).

Demographics

The demographics of the participating districts follows based upon the National School Lunch data found on the Pennsylvania Department of Education National School Lunch Program website (2009). This allows some insight into the social economic conditions of the districts that participated in the study.

School District	Enrollment	Free Lunch	Reduced Lunch	Percentage Free
		Eligible	Eligible	%
Н	395	151	44	38.2
D	1,534	483	83	31.5
А	2,756	658	169	23.9
С	4,002	933	295	23.3
В	2,660	556	278	20.9
Е	6,255	1,035	364	16.5
F	1,608	200	83	12.4
G	2,232	236	61	10.6
Ι	11,759	795	212	6.8

 Table 1: Demographics of Participating Schools

The location of the school districts was 3 suburban (33%), 4 residential (44%), and 2 rural (22%) total. The schools self identified themselves in these categories on their websites. There was a large percentage of schools from Western Pennsylvania 6 (67%), 2 (22%) from Northern Pennsylvania, and 1 (11%) from Central Pennsylvania. There were no districts from Eastern Pennsylvania represented in the study.

The data were collected over one semester from classrooms of teachers who agreed to participate in the study. A total of 18 teachers, representing 9 school districts, were employed in the study. A total of 107 students, 71 males and 36 females, volunteered to participate in the research project. In two of the ten schools there is no female representation in the study, this is due to the fact that no female students agreed to participate in the study at these locations. Data

analysis included only students who completed pre and post surveys. Data was analyzed from 107 matched pre and post surveys.

Study Design

One Mathematics and one Technology Education teacher from each school were required to participate in an orientation before beginning the study. The training session was performed at California University of Pennsylvania to familiarize the participating teachers with the Robotic Curriculum from Carnegie Mellon's NREC and the Lego NXT robotic kit that were to be used for the study. At this session the teachers were presented with the data supporting the reasoning behind this study. In addition, a member of the NREC curriculum development team aided the teachers in a demonstration of the video curriculum that was to be employed in the study. This curriculum was recently revised in conjunction with the University of Pittsburgh's Learning, Research and Development Center to narrow the focus of the mathematics concepts being covered to emphasize one specific area. The teachers collaborated, with each other, on which mathematics principles would be the focal point of their participation in the study.

When developing the study, the researcher was confident in the support of the Technology Educators' participation, but was aware of the need to gain support from the Mathematics educators. The method employed to win over the Math teachers was to assure them that there was no expectation to alter their current curriculum. The study allowed options of mathematics concepts that were standard in middle school math curriculum and were also focal points in the robotic curriculum. By embracing the math curriculum as an untouchable object, a majority of concerns from the math teachers were put at ease. With the math curriculum not changing collaboration was limited to the teachers aligning their activities for the study.

By incorporating existing robotic curriculum, the technology education teachers were able to easily show how their lessons would assist in the students' understanding of the mathematics concepts. Through this additional reinforcement of the concepts through real-world application, we expected to see an increase in students' awareness of the natural connection between mathematics and technology. The following is a list of the curriculum that was available for the teachers to select from for implementation of the study: measuring movement, turning (measuring distance), Pi wheel, direct and inverse proportionality, proportional distance, linear relationships, speed and Pythagorean Theorem.

The activities were delivered through multimedia presentations to increase student engagement. One example is that the students assume the role of a customer service representative for a robotic company that supplies hospitals with robots to deliver medicine to patient rooms. The hospital is having a problem with the robots appearing to not be traveling the correct distance. The students are required to troubleshoot the problem and report back to the nurses how to correct the problem. This allows the students to complete research to replicate the problem, test theories to provide a solution but also requires the students express the correction to the teacher.

During the training session, each team was required to complete the measurement activity to experience the lesson from the viewpoint of the student. Each team was required to pick which two concepts would be covered during the study implementation before leaving the session. Seven of the nine schools opted to implement the measurement and proportionality curriculum for the study. One selected proportionality and linear relationships and one selected Pythagorean Theorem curriculum. Proportionality is an area within the Pennsylvania System of School Assessment (PSSA) that is of great concern for many schools. The PSSA is administered to

determine whether standards set by the state and federal government are being met by students in Pennsylvania classrooms. The researcher believes that was a key reason in the majority of the schools selecting that curriculum for the study.

The study was executed in the Spring 2010 semester. Each of the participating schools established starting and ending dates for the study. As the study is based upon attitudinal research, the length of the execution was important. The robotic curriculum is designed to be presented over two to three class meetings (45 minute sessions). School districts differ on how technology education classes are assigned during the academic year. Some districts have students cycle through the technology education. Other schools distribute the technology education classes over the entire year where students meet once a week for technology education. A key component of the study was that the collaborated material be covered in no less that a minimum of two weeks but with a preference of an extended period of time spent on the activity. Three participating districts covered the material over a two week period while the remaining five districts completed over as much as 6 weeks. The districts that completed the study in two weeks meet with the students every day for two weeks while the districts that took longer to complete the study meet with the students once or twice a week for the technology class.

As the PSSA exams are delivered to the middle school students during the spring semester, scheduling the study dates was critical. A footnote to the schedule concerns was that Pennsylvania endured one if its snowiest springs on record, which led to many school cancellations and schedule adjustments.

Additionally, the way the schools assigned sections of math to students was a point of concern for the study. In most cases, not all of the students who participated in the technology

education class were in the math class with the collaborating teacher. This limited the number of students that were able to participate in the study. All of the students in the technology education class participated in the robotic curriculum, but only those students who were in the participating math teacher's class were able to complete the research surveys.

Instrument

The students' TEM beliefs and interest were collected using a pre-and-post NSF Fellow attitudinal survey containing Likert scale questions. With the limitation that the research was not addressing science, those sections of the survey were not made available to the students. Reverse coding of some statements was employed to reduce biasing effect (Tuckerman, 1999). Student agreement levels where measured with the Likert scaled questions (1-5, 1 being Strongly disagree – 5 Strongly agree) with 12 statements on TEM beliefs, and eight statements on TEM interest. These statements originated in the National Science Foundation's *Mississippi Information Technology Workforce* project; content validity for the statements was determined by 24 Mississippi agriculture and biology teachers (Lindner, Wingenbach, Harlin, Lee, Jackson, 2004).

The students were asked to complete a TEM attitude and interest survey (Appendix C) (pre) before starting the robotic activity and again at the completion of the activity (post). The activities concentrated on employing robotics along with professionally developed curriculum designed to focus on specific mathematics concepts. The survey consists of 12 statements pertaining to TEM beliefs and 16 statements pertaining to TEM interest. A Likert scale was employed to determine student agreement levels where 1 equals strongly disagree, 2 equals disagree, 3 equals neither agree nor disagree, 4 equals agree and 5 equals strongly agree with the statement. The science section of the survey was not made available to the students, due to the

fact that middle school science curriculum is not well suited for robotic activities. Therefore science teachers and their classes were not asked to participate in the study. The instrument was delivered in the traditional paper format.

The students were assigned random numbers by the teachers for completing the surveys from a master list. The master list assured that the students' post responses were able to be matched to the pre- instrument, therefore allowing analysis of matched student responses and student confidentiality.

The teachers were asked to audio record lessons delivered during the study implementation. These recordings were evaluated to address any discrepancies in the study by one school. Collaboration was significant for the success of the study. The teachers were instructed to reinforce in their lessons that the concepts were being supported in the collaborative teacher's classroom. In example, "Today we covered ratios and in Mr. Whitehead's technology class you will see these principles applied to robotics." This repetition was designed to aid students in the connectivity of the subject content areas.

The researcher was able to provide schools that did not have the robotic technology on site with ten Lego NXT kits plus the Mindstorm software for implementation. These kits were delivered to the school along with the surveys, digital audio recorder and consent forms (parent and student). Parents and students were allowed to opt out of the study at any time. The students that opted out still participated in the class work but were not asked to participate in the survey. The researcher had 30 kits available to distribute to the schools. Each school was allowed a maximum of ten kits for the study. Upon completion of the study the kits were returned to the researcher along with the collected data. Schools that did not require the robotic kits were delivered surveys, consent forms and digital voice recorders only.

The researcher entered the collected data into Statistical Package for the Social Sciences (SPSS) for evaluation. The data were evaluated to determine the results in correlation to the following research questions:

- What are the significant effects robotic centered activities significantly have in middle school students' STEM attitudes?
- 2. What are the significant effects robotic centered activities have in middle school students' STEM interests?
- 3. What is the significant relationship that exists between robotic centered activities and classroom inquiry levels?
- 4. What is the significant relationship that exists between classroom collaboration and middle school students' STEM interests and attitude changes?

The following research hypotheses were generated to aid in the evaluation of the data as it pertains to the research questions.

- There will be a significant increase in middle school students' Technology, Engineering and Mathematics attitudes as a result of the robotic centered activity.
- 2. There will be a significant increase in middle school students' positive attitude towards Technology, Engineering and Mathematics attitudes as a result of the collaborative activities between Math and Technology Education departments.
- There will be a significant number of participants who wish to take more Technology, Engineering and Mathematics classes as a result of the collaborative activity.

- 4. There will be significant increase in numbers of participants who like to find answers to questions by doing experiments in Technology, Engineering and Mathematics classes as a result of the collaborative activity.
- There will be a significant number of participants who report that Technology, Engineering and Mathematics classes are not difficult for them as a result of the activity.
- 6. There will be a significant increase in numbers of participants who plan on attending college as a result of the collaborative activity.
- There will be a significant increase in numbers of participants who try their best in Technology, Engineering and Mathematics classes as a result of the collaborative activity.

In chapter 4 the analysis of the data collected throughout the study by the participants will be examined closely to see if the use of the robotic activity and collaborative classrooms had any impact on the students' attitudes and interests toward TEM concepts and areas.

CHAPTER 4

RESULTS

The chapter details the findings of the study based upon the research objectives. The purpose of the study was to investigate if the use of robotics, along with collaboration between Mathematics and Technology Education teachers, can curtail the negative shift of middle School students' attitudes and interests toward Technology, Engineering and Mathematics. An alpha level of 0.05 was used to determine statistical significance throughout the analysis.

Research Question One

Research Question:

What are the significant affects robotic centered activities have in middle school students' STEM attitudes?

Hypothesis:

There will be a significant increase in middle school students' Technology, Engineering and Mathematics attitudes as a result of the robotic centered activity.

A paired t-test analysis was performed on the TEM data of pre versus post student responses to determine if there was a significant difference. Six questions from the belief survey were selected for evaluation. The data show that students' attitudes were more positive after the implementation of the collaborative robotic activity. Table 2 illustrates the results of the analysis along with which questions showed significant differences between the pre and post assessment. The questions are arranged from the largest pre post difference to the smallest difference. Cohen's d was calculated to determine effect size by evaluating the difference in means in terms of standard deviation units. It is agreed that 0.2 to 0.3 is small, 0.4 - 0.7 is medium and 0.8 to 1.0

is considered large effect size. Cohen (1990), "effect size measures include mean differences (raw and standardized).... whatever conveys the magnitude if the phenomenon of interest appropriate to the research content" (page 1310).

Survey	Pre Mean	Post Mean	P value	Cohen's d
Statement	(std dev)	(std dev)		
I want to take	3.04	3.38	0.02*	0.27
more	(1.25)	(1.23)		
technology				
classes.				
I enjoy	3.74	3.90	0.14	0.15
technology	(1.08)	(1.08)		
class.				
I think I could	3.23	3.39		
be a good	(1.09)	(1.14)	0.18	0.14
technologist.				
Technologists	4.07	4.21	0.32	0.08
help make our	(1.14)	(0.86)		
lives better.				
Technology is	4.02	4.15	0.35	0.12
useful in	(1.16)	(0.94)		
everyday life.				
Being a	3.23	3.32	0.00*	0.08
technologist	(1.18)	(1.08)		
would be				
exciting.	2.5.			0.1.5
Mean	3.56	3.73	0.08	0.15
I echnology	(1.15)	(1.06)		
Attitudes				
Kating				

Table 2: Technology Attitudes Paired Sample T-Test Results

- signifies statistical significance

All of the statements showed the same directional change, and only two statements showed statistically significant changes. Two questions that had significant difference attributed to the alpha value of less than 0.05 where; *Being a technologist would be exciting* and *I want to take more technology classes*. A key factor for the positive responses to, *I want to take more technology classes*, may be the use of robotics only during the technology class session. This was the first introduction of robotic activity at a majority of the schools that participated in the study.

The experience of using the robots in class also allowed students to experience first-hand some of the daily tasks associated with being a technologist. The use of video presentations to

describe scenarios was a new approach for many of the teachers as well as the students. This form of presentation for content may also have influenced the students' responses.

The evaluation of the data concentrating on the students' attitudes towards engineering demonstrated an increase in relationship to five of the six statements. None of the schools that participated in the study had an engineering class; engineering was covered in the technology education session of the students' schedules. Table 3 illustrates the findings based upon students' interest towards engineering.

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
Being an	3.14	3.34	0.25	0.17
engineer would	(1.29)	(1.09)		
be exciting.	2 20	2 20		
he a good	3.20	3.38	0.00*	0.15
engineer.	(1.28)	(1.19)	0.00*	0.15
I enjoy	3.38	3.53	0.00*	0.13
engineering	(1.21)	(1.12)		
class.			0.01.1	0.00
I want to take	3.15	3.26	0.01*	0.09
more	(1.23)	(1.21)		
classes				
Engineers help	4.08	4.13	0.04*	0.05
make our lives	(0.81)	(1 00)		
better.	(0.01)	(1.00)		
Engineering is	4.34	4.01	0.45	0.29
useful in	(1.21)	(1.05)		
everyday life.				
Mean	3.60	3.66	0.73	0.04
Engineering	(2.10)	(1.16)		
Belief Rating				

 Table 3: Engineering Attitude Paired Sample T-Test Results

* - signifies statistical significance

Engineering attitudes indicated an improvement in students' responses were mostly positive. Post scores on students' attitudes towards engineering were higher than pre scores on four of the five statements. The largest increase (0.18) was in relationship to the statements *I think I could be a good engineer*. The explanation for the large increase in regards to these

statements correlates to students having given little thought to what the everyday tasks of an engineer are before encountering the robotic activity. The activity was designed to simulate real life work experiences to the students with the focus on mathematics and robotics. Through the completion of the activity the students assumed the role of an engineer assigned the task of solving customer's problems that required a specific mathematical concept for success.

One statement, *engineering is useful in everyday life*, reflected a decrease with a loss of 0.34 in the students' attitude. The reason for this negative effect is hard to explain but a possible solution is that students focused in robotic engineering specifically and failed to see the larger impact of engineering on their everyday lives. Another possible reason behind the decrease is the students' experience was over a short period of time and they did not fully grasp the broad area of study that encompasses engineering.

Post survey responses on students' attitudes towards math were higher than pre test scores on five of the six statements. Table 4 illustrates the student responses to the statements with the statements displayed in the largest increase on top of the table and the smallest at the bottom. The greatest increase of 0.27 points was identified with the statement *math is useful in everyday life*. The reason for this increase may be directly related with the robotic curriculum presenting the mathematical concepts covered in the students' math class being presented to solve real world problem scenarios. The teachers made explicit connections across the curriculum in the presentation of the material. The technology teacher reinforced material presented during math class by stating the concept presented in math class today is being applied to our robots today.

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
Math makes	3.71	3.99	0.00*	0.27
our lives better.	(1.09)	(0.97)		
Math is useful	3.96	4.23		
in everyday life.	(1.14)	(1.00)	0.00*	0.25
Being a	2.65	2.80	0.00*	0.12
mathematician	(1.23)	(1.20)		
exciting				
I want to take	2.85	2.99	0.00*	0.11
more math	(1.28)	(1.36)		
classes.	()	()		
I think I could	3.08	3.17	0.00*	0.07
be a good	(1.24)	(1.27)		
Leniov math	3 57	3 / 8	0.10	0.05
class	(2, 20)	(1.27)	0.10	0.05
	(2.20)	(1.27)		
Mean	3.31	3.43	1.86	0.08
Mathematics	(1.49)	1.27)		
Bellef Kating				

Table 4: Math Attitude Paired Sample T-Test Results

* - signifies statistical significance

One statement, *I enjoy math class* signified a decrease of 0.09 points. The students may view the additional robotic curriculum in Technology education as a "one time occurrence" therefore the expectation is that the math curriculum will return to a stand alone curriculum taught without connection to other areas when the study was completed. Another key factor is the timeframe in which the study was completed. The study was administered over a short period of time, which may simply have not been long enough to show any significant change in students' interest toward math class.

Research Question Two

Research Question:

What are the significant affects robotic centered activities have in middle school students' STEM interests? Hypothesis: There will be a significant increase in middle school students' Technology, Engineering and Mathematics interests as a result of the robotic centered activity.

A paired t-Test analysis was performed on the technology interest data of pre versus post student responses to determine if there was a significant variation in the relationship between the pre and post data. Three statements from the interest survey were selected for evaluation. The three statements examined are: *I think technology is important only at school, the things we study in technology are not useful to me in daily life,* and *I like technology more than all other subjects.* The data was reverse coded for the statements, *I think technology is important only at school* and *I like technology more than all other subjects* based upon the statements having negative conations.

The data show that students' interests were slightly more positive in technology for two of the statements. Table 5 illustrates the results of the analysis along with which statements showed significant differences between the pre and post assessment. The statements are arranged in order of highest difference to lowest difference in students' response average.

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
I think	2.01	2.05	0.03*	0.04
technology is	(0.89)	(0.95)		
only important	~ /			
at school**	• • • •	2.00	0.10	0.01
I like	2.99	3.00	0.18	0.01
technology	(1.10)	(1.06)		
other subjects				
in school				
The things we	2 27	2 13	0.00*	0.12
study in	(1.16)	(1.15)	0.00	0.12
technology	(1.10)	(1.13)		
class are not				
useful to me in				
daily living. **				
Mean	2.37	2.43	0.78	0.05
Technology	(1.14)	(1.13)		
Interest rating		× ,		

Table 5: Technology Interest Paired Sample T-Test Results

* - signifies statistical significance ** - signifies data was reverse coded

The paired t-test analysis indicated that students' technology interests became more positive on two of the three statements. Students gained technology interest in *I think technology is only important at school* (0.04) and *I like technology more than all other subjects in school* (0.01). A reason for these changes may be related to the students' first experience with the robotic curriculum. The excitement of using robotic technology in the technology class may have triggered interest in the students to continue to participate in technology related classes. Students' moderate interest is perhaps attributable to the robots being removed from the schools upon completion of the study.

The influence on the statement, *the things we study in technology are not useful to me in daily life was a change of* (0.14). This is one of the two statements that were reverse coded. The students may have determined that what they learned during the study was useful in their daily lives based upon the robotic activities being designed to replicate a real world scenario.

A paired t-test analysis was performed on the engineering interest data of pre versus post student responses to determine if there was a significant relationship between the pre and post results. The data show that students' interests were more positive in engineering for all of the statements. Table 6 illustrates the results of the analysis along with which questions showed significant differences between the pre and post assessment.

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(sta dev)	(sta dev)		
I like engineering more than all other subjects in school.	2.76 (1.02)	3.02 (1.07)	0.00*	0.25
I think engineering is important only at school. **	2.17 (0.99)	2.21 (1.03)	0.01*	0.04
The things we study in engineering class are not useful to me in daily living. **	2.33 (1.14)	2.35 (1.06)	0.48	0.02
Mean Engineering Interest rating	2.42 (1.08)	2.53 (1.11)	1.44	0.10

 Table 6: Engineering Interest Paired Sample T-Test Results

* - signifies statistical significance ** - signifies data was reverse coded

Two statements demonstrated statistically significant changes between of 0.02 and 0.04 respectfully. A reason for these slight changes may be attributed to the fact that students were selecting between technology, engineering and math classes at the same time. Technology and engineering are taught in the same class session and the math class was utilized in collaboration for the study. The students may have increased beliefs and interest overall for all classes which was signified as a small increase in all three categories and not a large increase in relationship to one specific area.

A paired t-test analysis was performed on the math interest data of pre versus post student responses to determine if there was a significant relationship between the pre and post results. The data show that students' interests were more positive in math for all of the three statements. Table 7 illustrates the results of the analysis along with which questions showed significant differences between the pre and post assessment.

Survey Question	Pre Mean (std dev)	Post Mean (std dev)	P value	Cohen's d
I think math is important only at school.**	2.01 (1.10)	2.29 (1.29)	0.23	0.24
The things we study in math class are not useful to me in daily living. **	2.23 (1.25)	2.25 (1.10)	0.01*	0.02
I like math more than all other subjects in school.	2.98 (1.32)	3.01 (1.31)	0.15	0.02
Mean Mathematics Interest Rating	2.42 (1.29)	2.51 (1.28)	1.15	0.07

 Table 7: Math Interest Paired Sample T-Test Results

* - signifies statistical significance ** - signifies data was reverse coded

The data illustrated that students' math interest slightly increased on two statements, *I like math more than all other subjects in school* (by 0.03). The reason for this change may be an increased awareness of the application of mathematics in the real world. Once again even though the change is slight three categories saw in increase on this statement. This shows the students gained an appreciation for each class.

The other two statements signified an increase, *the things we study in math class are not useful to me in daily living*, and *I think math is important only at school*. Both of these statements have negative connotations so the data were reverse-coded for the statistical analysis. The change in students' interest in regards to math may be related to the experience of seeing math

concepts being applied to real world scenarios. Showing the students how the math concept is employed in an everyday task gives additional meaning and worth to the reason for developing this mathematical knowledge. For many of the students this may have been the first time a math concept was reinforced outside of the math class session.

Research Question Three

Research Question:

What is the significant relationship that exists between robotic centered activities and classroom inquiry levels? Hypothesis: There will be a significant increase in numbers of participants who like to find answers to questions by doing experiments in Technology, Engineering and Mathematics classes as a result of the robotic centered activities.

The analysis of the data to respond to research question 3 was based upon 3 questions from the student belief survey and 2 questions from the student interest survey. The questions for this analysis were selected based upon the determination that each statement was associated with an example of inquiry based techniques. The statements selected for analysis were:

Belief Survey

Question 3 – I like to find answers to questions by doing experiments.
Question 4 – I get to do experiments in
(technology/engineering/mathematics) class
Question 7 – I like to use the (technology/engineering/mathematics) book
to learn.

Interest Survey

Question 4 – I like to use (technology/engineering/mathematics) equipment to study (technology/engineering/mathematics).
Question 8 – Technology class activities are boring to me.

The results for the interest survey question 8 statement were reverse coded due to the negative reflection of the statement. The students' pre versus post responses to these questions were analyzed with a paired t-test analysis.

The paired t-test analysis indicated that the technology classroom inquiry level was more positive after the implementation of the collaborative robotic activity. Students gained technology interest in relationship to all 5 statements: *I like to use technology equipment to study technology* (+0.46), *I like to find answers to questions by doing experiments* (+0.38), *Technology class activities are boring to me* (+0.28), *I get to do experiments in te*chnology *class* (+0.17), and *I like to use the technology book to learn* (+016) (See table 8).

Table 8: Technolog	[,] Interest Research	Question 3	Results
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Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
I like to use technology equipment to study technology.	3.32 (1.25)	3.78 (1.05)	0.63	0.40
I like to find answers to questions by doing experiments.	3.40 (1.07)	3.78 (1.07)	0.00*	0.36
Technology class activities are boring to me. **	2.25 (1.09)	2.48 (1.09)	0.00*	0.21
I get to do experiments in technology class.	3.54 (1.06)	3.71 (1.08)	0.11	0.16
I like to use the technology book to learn.	2.08 (0.93)	2.24 (1.14)	0.07	0.15
Mean Technology Interest Rating	2.95 (1.23)	3.15 (1.31)	0.18	0.16

* - signifies statistical significance **signifies reverse coded

All statements showed a positive reflection in the students' inquiry level at the completion of the study. Students responses to these statements allow a clear conclusion that their inquiry level had increased based upon the experience of the robotic activity. The statement that increased the least is related to the usage of the technology book, for the research project no technology book was utilized which may account for the change. The other statement changes can be related directly to the students experience completing the robotic activity including the usage of the robotic kit, the employment of the robotic curriculum and robotic software.

The paired t-test analysis indicated that the engineering classroom inquiry level was more positive after the implementation of the collaborative robotic activity. Students gained engineering interest in 4 of the 5 areas. The increase for each of the 4 statement was: *I get to do*

experiments in engineering class (+ 0.30), Engineering class activities are boring (+0.26), I like to find answers to questions by doing experiments (+0.24), and I like to use the engineering book to learn (+ 0.19). All of these increases show that the students enjoyed the opportunity to do the robotic experiment and seek answers on their own through the resources that were available to them.

One statement was less positive after the activity; *I like to use engineering equipment to study engineering* (-0.02). As stated previously a majority of the schools experienced the Lego Robotics and the Mindstorm software required to program the robot for the first time during the study. As with any technology and software there is a learning curve and students may have struggled with the technology which may have negatively impacted their beliefs toward engineering. The results are listed in table 9 from the largest to smallest change.

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
Engineering class activities are boring to me. **	2.47 (1.14)	2.73 (1.18)	0.18	0.22
I get to do experiments in engineering class.	3.24 (1.13)	3.54 (1.05)	0.03*	0.28
I like to find answers to questions by doing experiments.	3.41 (1.20)	3.65 (1.19)	0.02*	0.20
I like to use the engineering book to learn.	2.26 (1.09)	2.45 (1.16)	0.03*	0.17
I like to use engineering equipment to study technology.	3.53 (1.08)	3.51 (1.12)	0. 09	0.02
Mean Engineering Interest Rating	2.88 (1.23)	3.02 (1.21)	0.05	0.12

* - signifies statistical significance **- signifies reverse coded

The paired t-test analysis indicated that the math classroom inquiry level was more positive after the implementation of the collaborative robotic activity. Students gained mathematics interest in relation to 3 of the 5 statements. The differences for each statement follow: *I like to use math equipment to study math* (+0.25), *I like to find answers to questions by doing experiments* (+0.12), *I get to do experiments in math class* (+0.09). All of these statements can be directly related to the students' experience of using the robotic technology in the technology class as positively impacting the students' math attitudes. The students were using the robotics to solve mathematical problems that were related to real world scenarios during the technology class session. For many of these students it was the first experience seeing math applied with technology, which influenced their attitudes toward math.

One statement was less positive after the activity; *I like to use the math book to learn* (-0.08). The decrease in this area may be related to math being taught through hands on activities in the technology classroom versus existing techniques. Students have previously been learning math through doing math exercises from the textbook. The students' experience of seeing math applied in a physical sense may have influenced their desire to learn math through a technological application.

One statement showed no increase or decrease: *Math class activities are boring* (0.00). This may be true since the math curriculum was not adapted at all for the study. Math was taught in the same manner throughout the study with the only change being that the mathematical concepts were reinforced in the technology class with the use of robotics. (See table 10)

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
I like to use	3.25	3.50	0.00*	0.22
math	(1.15)	(1.17)		
equipment to				
Llike to find	2 25	2 47	0.00*	0.11
answers to	(1.12)	(1.09)	0.00*	0.11
questions by	(1.12)	(1.08)		
doing				
experiments.				
I get to do	2.97	3.06	0.01*	0.08
experiments in	(1.15)	(1.24)		
math class.	0.51	0.51	0.00	0.00
Math class	2.71	2.71	0.08	0.00
activities are	(1.16)	(1.18)		
L like to use the	2.81	2 73	0.00*	0.06
math class	(1.10)	(1, 41)	0.00*	0.00
book to learn.	(1.19)	(1.41)		
Mean	3.02	3.09	0.21	0.06
Mathematics	(1.18)	(1.30)		
Interest Rating	((1.00)		

* - signifies statistical significance **- signifies reverse coded

Research Question 4

Research Question:

What is the significant relationship that exists between classroom collaboration and middle school students' TEM interests and attitude

changes?

Hypothesis:

There will be a significant increase in numbers of

participants who wish to take more Technology, Engineering and

Mathematics classes as a result of the robotic collaborative activity.

Data analysis was performed on the student responses to question twelve in the belief

section of the survey; I want to take more (technology/engineering/mathematics) classes, along

with interest questions seven and fourteen, I like to work in small groups in

technology/engineering/math class, and I like (technology/engineering/mathematics) classes

more than all other subjects.

The paired t-test analysis indicated that the classroom collaboration was positive for all technology categories. (See table 11). The gains in technology interest for all three statements were: *I want to take more technology classes* (+ 0.34), *I like to work in small groups in technology class* (+0.34), and *I like technology class more than any other class* (+ 0.01).

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
I want to take	3.04	3.38	0.00*	0.28
more	(1.25)	(1.23)		
technology		, , , , , , , , , , , , , , , , , , ,		
classes.				
I like to work	3.53	3.87	0.11	0.30
in small groups	(1.17)	(1.06)		
in technology		× ,		
class.				
I like	2.99	3.00	0.15	0.01
technology	(1.16)	(1.14)		
class more than				
all other				
subjects.				
Mean	3.20	3.40	0.01*	0.17
Technology	(1.22)	(1.21)		
Interest Rating	()	()		

Table 11: Student Technology Interest from Collaboration Research Question 3 Results

* - signifies statistical significance

The positive change in all three statements responses from students can be related to the students' first exposure to collaboration between technology education and mathematics. The teachers were very aware to constantly remind the students how each class's material was being utilized to help the students better understand the concepts of technology, engineering and mathematics. The teachers would make statements during their presentations such as "Today in Mr. Whitehead's technology class you will be using the Lego Robotic to study proportions

which we are covering now." These statements were explicated and were designed to aid students to see the direct connections between the curricula. The math teachers were impressed with the video presentations available for use by the technology educators when first introduced to the study which speaks highly of the presentation material emphasizing the collaboration.

The paired t-test analysis indicated that the classroom collaboration was positive for all three engineering categories. (See table 12). The gains in student engineering interest for each statement were: *I like to work in small groups in engineering class* (+0.31), and *I like engineering class more than any other class* (+0.26), and *I want to take more engineering classes* (+0.11) (See table 12).

Table 12: Student Engineering Interest from Collaboration Research Question 3 Results

Survey Question	Pre Mean (std dev)	Post Mean (std dev)	P value	Cohen's d
I like to work in small groups in engineering class.	3.42 (1.10)	3.73 (1.08)	0.02*	0.29
I like engineering class more than any other classes.	2.76 (1.02)	3.02 (1.07)	0.00*	0.25
I want to take more engineering classes.	3.15 (1.22)	3.26 (1.21)	0.01*	0.09
Mean Engineering Interest Rating	3.09 (1.15)	3.31 (1.15)	0.04*	0.19

* - signifies statistical significance

The positive influence for all the engineering statements can be related to the students' experience of seeing through hands-on experiments how technology, engineering and math all correlate to one another through the collaborative activities. The experience of seeing how math

is employed in engineering and seeing the implications through the application with the robot had a positive influence on the students.

The paired t-test analysis indicated that the classroom collaboration had a positive influence for all three of the math categories (See table 13). The gain for math interest in all three statements was: *I like to work in small groups in math class* (+0.43), *I want to take more math classs* (+0.14), and *I like math class more than any other class* (+0.03).

Survey	Pre Mean	Post Mean	P value	Cohen's d
Question	(std dev)	(std dev)		
I like to work	3.58	4.01	0.74	0.42
in small groups in math class.	(1.10)	(0.94)		
I want to take	2.85	2.99	0.00*	0.11
more math	(1.27)	(1.36)		
classes.				
I like math	2.98	3.11	0.00*	0.02
classes more	(1.32)	(1.31)		
than all other subjects.				
Mean Math	3.33	3.33	0.97	0.00
Interest Rating	(1.22)	(1.31)		

Table 13: Student Math Interest from Collaboration Research Question 3 Results

* - signifies statistical significance

The reason for the math increase can be related to students experiencing firsthand how math is employed in technology and engineering professions. Math being taught outside of the confines of math class was interesting to the students. Having the opportunity to work in small groups allowed the students to utilize each other's expertise when problem solving. Observing a positive increase in students' willingness to take more math classes was encouraging and is attributed to the collaboration activity.

Summary

In conclusion the collaborative robotic activity was successful. Through the analysis of the data the findings show that students' beliefs and interest were positively affected by participating

in the study. There are several outside factors that need to be considered when reviewing these data, including that the majority of the students were experiencing the robotics for the first time.

In addition the professional multimedia presentations used in the technology education class to present the mathematical activities to the students needs to be considered as an influence in any change indentified in the study. The way the technology and engineering material was presented to the students was different than the teacher simply lecturing to them as students were accustomed to in the class. The use of video presentations to describe the scenarios was a new experience for all of the students involved in the study. During the teacher training sessions, seven of the nine math teachers agreed to participate after seeing how professional the curriculum material was for the collaboration with technology education.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to demonstrate how robotics, as a content organizer, can change middle school students' STEM interests and beliefs as a function of inquiry based learning. The study focused only on Technology, Engineering and Mathematics (TEM) because the middle school science curriculum is not easily adaptable for demonstration with robotics. To accomplish this purpose, the following objectives were established:

Determine if robotic centered activities significantly affect middle school students'

TEM attitudes.

- Determine if robotic centered activities significantly affect middle school students' TEM interests.
- Determine if a significant relationship exists between robotic centered activities and classroom inquiry level.
- Determine if a significant relationship exists between classroom collaboration and middle school students' TEM interests and attitude changes.

The study was designed around the collaboration of middle school mathematics and technology education teachers. LEGO robotics were utilized during the technology class session to reinforce a mathematical concept being covered during the students' math session. Each teacher was expected to reinforce the collaboration to the students with audio clues, such as "Today in Mr. Phillips technology class you will study gears, which is a direct example of the mathematical concept proportionality which we are discussing today."

The study consisted of 9 middle schools, 18 teachers and 107 middle school students. The cooperating teachers met for professional training on the Lego NXT robotic kit and the robotic curriculum developed at the National Robotic Educational Center (NREC). During the training session each pair of teachers identified the mathematical concepts that would be the focus of their school's study and a tentative start and a completion date. All teachers were asked to have the study extend over three to five weeks during the implementation of the study.

Pre and post instruments for Technology, Engineering and Mathematics (TEM) interest and beliefs were administered to the students to determine any level of change in the participants. The survey consisted of 12 statements pertaining to TEM beliefs and 16 statements pertaining to TEM interest. A Likert scale was employed to determine students' agreement level with each statement: 1 strongly disagree, 2 disagree, 3 neither agree nor disagree, 4 agree and 5 strongly agree. t-test analysis was applied to the data to identify any significance at the 0.05 level. Based upon the results of the study it can be inferred that the middle school students: developed a positive increase in TEM beliefs; developed a positive increase in TEM interest; developed a positive experience of robotics as instructional tools and developed an increased awareness of TEM concepts application in daily tasks

Objective One

Objective one endeavored to determine the effect of robotic centered activities on participant's TEM attitudes. The data were collected over 2 to 6 weeks from belief and interest surveys administered as pre and post surveys. Throughout the activity, participants were engaged with collaborative practices between mathematics and technology education. Math concepts were reinforced during the technology class session with the aid of the NREC's robotic

curriculum. The math and technology teachers worked in partnership to assure students where able to draw connections between the math theory and real world applications.

The findings for objective one were not statistically significant on all items, but overall the differences were significant to support the hypothesis that robotic centered activities would have a positive affect on middle school students' TEM beliefs. This was shown in reviewing the data with the students' having an increase in *wanting to take more technology/engineering/math classes*, and *being a technologist/engineer/mathematician would be exciting*. Overall students demonstrated an increase in mathematics attitudes to the majority of the statements reviewed in relationship to the objective.

The study findings support that collaboration between the mathematics department and technology education can have a meaningful effect on students' attitudes toward TEM concepts, educational paths and careers. This research project exemplified multi-disciplinary curricula, a structure that closely coupled disciplines and was not an attempt to integrate the subjects (Black & Atkins, 1996). The underlying theme is if students are going to understand a concept they must apply it themselves; in addition the students need to reflect upon the application. The robotic curriculum required the students to solve a mathematical problem and also be able to explain how the problem was resolved, therefore allowing the students the opportunity to evaluate their own reasoning of the solution.

Objective Two

Objective two aimed to demonstrate that a positive relationship exists between robotic centered activities and middle school students TEM interests. The surveys enabled the researcher to collect data to detail any positive change in students' TEM interest throughout the study.

The findings for research question two were not statistically significant for all items however the overall findings supported the hypothesis that robotic centered activity would have a positive affect on middle school students' TEM interests. There was a significant increase in students' attitudes toward *I like technology/engineering/math class more than any other in school*. All the schools that participated in the study did not have an engineering class, but engineering concepts were covered in the technology class.

The introduction of the robotics was a new experience for a majority of schools that participated in the study; this may account for some of the increase in students' interest to TEM in relationship to these classes. The results indicate that the experience of having math concepts presented in a meaningful way, coupled with the use of the robotic technology, had a positive influence on the students. The students were directed to assume the role of an engineer who was required to resolve a problem a customer was having with a newly acquired robot. The students needed to test, generate a hypothesis for resolving the error and then report the solution back to the customer. This activity transferred responsibility for the students' learning to the students themselves, and in doing so increased the students' enjoyment for the classes.

Objective Three

Objective three was to establish that a positive relationship exists between robotic centered activities and classroom inquiry levels. The surveys enabled the researcher to collect data to detail any positive change in students' TEM belief and interests over the period of the study.

The findings for research question three were not all statistically significant, but there were enough significant findings to support the hypothesis that robotic centered activities increased the classroom inquiry level. Across all three TEM areas there was a significant positive change

on students' inquiry level based upon their responses to *I like to find answers to questions by doing experiments*.

The robotic activity is not designed to allow the students to memorize information and be successful. The activity is designed to allow the students to think independently, allow them a sense of contact with the real world and force them to express their own ideas. For a majority of the students this was a new experience which they responded to in a positive way.

Objective Four

Objective four was to determine if a significant relationship exists between classroom collaboration and middle school students' TEM interests and attitude changes. There was a significant association with students' TEM interest and attitudes in relationship with the classroom collaboration.

The collaboration allowed the students the opportunity to see the natural connection between all three areas: Technology, Engineering and Mathematics. By asking the students to assume the role of a technologist/engineer/mathematician and resolve a real-world scenario, there was a breaking of the smoke-stack curriculum for the students. The concepts blended into one instead of being taught separately from one another with no connection for the students to easily link to one another.

Implications

The findings reveal that robotic centered activities along with classroom collaboration can aid to reverse middle school students' negative beliefs and interests toward TEM. Through collaboration between the mathematics and technology education departments the study was able to indicate a positive influence on students' TEM beliefs and interests. The effect size of the paired *t* test analyses were measured by Cohen's *d*. Examination of the *d* for the statistically
significant findings showed only a small effect size. A reason for this small effect size may be the length in which the study was completed. In conclusion, the results of the study indicate the magnitude of the pre – post survey were the result of the robotic intervention but that those differences were mainly small. Four to six weeks may simply not be long enough to result in large change in students' beliefs and interests.

An important point to consider is that math maintained its integrity, but technology was used to show real world applications of the math principles with the introduction of robotics. The activity highlighted not interdisciplinary but multi-disciplinary curriculum, as the curriculums that paralleled each other were reinforced with the utilization of the robotic technology.

The results have the potential to lead in the development of collaboration between disciplines aiding in having a positive impact on middle school students' beliefs toward STEM careers and educational paths. Through the exploitation of robotics, teachers are able to build a classroom of inquiry where students can see real world applications of mathematics and engineering principles. This allows the students to draw conclusions to the usefulness of these concepts in every day life. These types of experiences have the ability to increase students' willingness to pursue careers, or educational opportunities, in STEM areas.

Recommendations

The importance of STEM education is at the political forefront in the United States of America. It is imperative that educators actively engage to reverse the negative grade level effect of students' attitudes toward STEM concepts and related areas. To reverse this negative trend, teachers, administrators, and parents should work to develop collaboration not only between curriculums, but also with STEM professionals in the classrooms.

65

New approaches to teaching science, technology, engineering and mathematics with an emphasis on connections between the fields need to be developed and employed. Educators do not need to develop complicated inter-related disciplinary activities but a multidisciplinary activity with an emphasis on how concepts from each curriculum area are paralleled in one another that is demonstrated to the students. Collaboration between the faculties should focus on three basic ideas: allow students the opportunity to think on their own, allow the students the opportunity to connect concepts with real world scenarios, and require the students to express their own ideas in the classroom. By increasing the range of learning activities in the classrooms, a larger range of students are given the opportunity to become interested in STEM areas.

Recommendation for Future Studies

Future studies could address the limitations of this study. One way to build upon this study is to extend the timeframe over the entire school year or even follow sixth grade students through the completion of eighth grade. This would allow more data to be collected and the collaboration could be performed more effectively. In addition, the selection process of schools to participate could be restricted to only schools that are using educational robotics currently, therefore removing the excitement of a new technology as an influence on the students' attitudes.

The research design could be enhanced by adding a qualitative element by including student interviews. These interviews would allow the researcher a chance to gain important insight as to what were some of the contributing factors to the student's changes in pre versus post results. Furthermore interviewing teachers based upon their experience, from their expectation at the start of study through the implementation and conclusion could be helpful in improving collaboration and activities.

66

Future studies may also wish to focus on gender analysis as the need to increase the number of females in the STEM areas is a focal point in the current educational arena. Two of the schools that participated had no female representation for the study. When the teachers were questioned on this matter, they expressed their feeling that a popular girl had influenced other girls to not participate in the study. This may be an opportunity to research the effect of peer-pressure and gender stereotyping on girls' willingness to pursue STEM studies. In addition further research could examine if robotics and collaboration offer an opportunity to increase girls' attitudes toward STEM.

Future studies should also examine the impact of the collaboration and robotic curriculum on the teachers. Were the teacher's attitudes influenced by participating in the study? By interviewing the teachers at the start and close of the activities a qualitative element would be added to strengthen the findings.

Conclusion

For America to maintain its superpower status it is imperative that everyone pulls together to reverse the negative perceptions related to STEM areas that develop within middle school students as they progress toward high school. To create this change we must help teachers to work smarter, not harder. The majority of educators see the connectivity between STEM curriculums and yet educators still feel their area of specialty is best suited to address STEM without the aid of the others. It is no longer acceptable to teach science, technology, engineering and mathematics as individual concepts that are only taught at certain times each day. Educators do not need to create elaborate inter-related activities but should begin with drawing upon the parallels that exist between these fields and increase collaboration. William Shakespeare's character Puck, a clever and mischievous elf from *A Midnight Summer's Dream*, concludes the play with the following quote which is fitting for the end of this conversation also: (*W. Shakespeare*) Retrieved October 5, 2010, from http://www.shakespeareonline.com/plays/mids_5_1.html

> "If we shadows have offended, think but this; and all is mended that you have but slumbered here while these visions did appear and this weak and idle theme no more yielding but a dream. Gentles--do not reprehend if you pardon, we will mend. And, as I am an honest Puck, if we have unearned luck. Now to scape the serpents tongue. We will make amends ere long; else the Puck a liar call. So--goodnight unto you all. Give me your hands if we be friends. And Robin shall restore amends (Act V, Scene I)."

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Appendix A Parent Consent Form

Internal Review Board

250University Avenue

California, Pennsylvania 15419 instreviewboard@cup.edu

Working Title: Relationship of robotic implementation on changes in Middle school students' beliefs and interest toward Science, Technology, Engineering and Mathematic

Dear Parent or Guardian,

Your child has been invited to participate in a project that is trying to improve students' interest in Science, Technology, Engineering and Mathematics through the use of robotics in the mathematic and technology education classroom. The following information is provided so that you are able make an informed decision of whether or not to allow your child to participate in this activity. Your child qualifies to participate in this study because he/she is middle school student in the participating teachers' classes. Participation is voluntary with the understanding that the participants can withdraw from the research at any time by contacting me via email or postal letter or telephone. Contact information has been included at the conclusion of this letter. Willingness to participate or not participate in the study has no effect on academic grades. Again, participation is completely voluntary.

This 10 minute survey will be completed twice, once at the start of the lesson module and at the conclusion. Your child will be asked to respond anonymously to a set of questions that are administered via paper and pencil. Along with the survey, a small number of participants will be asked to share their thoughts about STEM in an interview. The interview will be conducted during a 10-20 minute conference during the class period. Their responses will be tape-recorded and later transcribed for research purposes. Again, anonymity will be maintained. Any presentation or publication that discusses the findings of this research will continue to maintain anonymity by using pseudonyms in order to protect the identity of all participants. Results will be maintained for five years in a locked cabinet in my office only the researcher and my faculty lead will have access to the records.

This study is being conducted for research purposes, and there are no known risks in participating in this study. This study has been approved by the Internal Review Board (IRB) at California University of Pennsylvania effective October 5, 2009 and expires October 4, 2010. The STEM activity fits into the existing curriculum and your child will be able to participate in the activity regardless of if they participate in the survey and interview elements of the study. One potential benefit of this study, however, is that it will provide an opportunity for the student to grasp the natural connections between science, technology, engineering and mathematics.

If you are comfortable with your child participating in this research, please sign and date the attached paper and return it in the self-addressed envelope provided. A returned, signed letter implies your consent. If you need further clarification on the information presented, please feel free to contact me my contact information can be found at the bottom of this letter. An executive summary of the findings from this study will be made available to you upon request.

Thank you for your consideration.

Principal Investigator:

Stephen H. Whitehead, D.Ed candidate California University of Pennsylvania 115 Helsel Hall, CUP 250 University Avenue California, PA 15419 724-938-4060

Faculty Sponsor:

Dr. Kelli Jo Kerry-Moran Indiana University of Pennsylvania 125A Davis Hall, IUP 570 S. 11th Street Indiana, PA 15705 724-357-5689 kelli.kerry-moran@iup.edu

Parent Consent Form (continued)

VOLUNTARY CONSENT FORM:

I have read and understand the information on the form and I consent to volunteer to be a subject in this study. I understand that my responses are completely confidential and that I have the right to withdraw at any time. I have received an unsigned copy of this Informed Consent Form to keep in my possession.

Parent/Guardian Name (PLEASE PRINT)

Signature_____

Date	

Phone number or location where you can be reached ______

I certify that I have explained to the above individuals the nature and purpose, the potential benefits, associated with participants in this research study, and have answered any questions that have been raised.

Date

Principal Investigator's Signature

Appendix B Student Consent Form

Internal Review Board

250University Avenue

California, Pennsylvania 15419 instreviewboard@cup.edu

Working Title: Relationship of robotic implementation on changes in Middle school students' beliefs and interest toward Science, Technology, Engineering and Mathematic

Dear Student,

I would like you to help me with a research study. I am going to tell you about my research study so you may decide if you want to help me or not help me with this study. It is OK for you to ask me questions while I'm explaining my study to you. I appreciate your willingness to help me with my study.

I would like to know if using robotics in the classroom makes students more interested in Science, Technology, Engineering and Mathematics. Helping me with this study will take about 10-15 minutes of your time at the beginning of the teaching lesson and at the end. If you would like to help me, I will need to ask you some questions about your feelings toward Science, Technology, Engineering and Mathematics. You will be asked to answer a survey and may be interviewed by me at the end of the lesson. I will be recording our time together so I can remember it right later on when I do the homework for my study.

I promise not to be rude or trick you in any way when we are talking. You should have a nice time when we talk about robotics in your classroom together. The things I will learn from talking to you will help teachers like me to be better teachers.

No one is making you participate in the study, and you don't have to if you don't want to. If you don't want to be part of the study you will still have the opportunity to use the robotics in the classroom with the other students. If you decide later that you don't want to be part of my research study, you and your parent/guardian can tell me that by calling, emailing, or writing to me, and I will put the audio of our talk in the garbage and not include you in my study. If you do want to be in my study, nobody will know who you really are you will be assigned a random number that will keep your identity protected. I am talking about robotics with a lot of different people, and our talk together will just be a little part of the big research study. When I finish my research study, I might talk about what I learned with other people, or write it down so other people can read it, but I will always use your secret identity.

If you would like to help me in my study, please put your name on the bottom of this sheet. I have a copy of this form to give to you to keep, as well as one for your parent/guardian to keep. If you don't want to help me in my study, do not sign this sheet.

Principal Investigator:

Stephen H. Whitehead, D.Ed candidate California University of Pennsylvania 115 Helsel Hall, CUP 250 University Avenue California, PA 15419 724-938-4060 whitehead@cup.edu

Faculty Sponsor:

Dr. Kelli Jo Kerry-Moran Indiana University of Pennsylvania 125A Davis Hall, IUP 570 S. 11th Street Indiana, PA 15705 724-357-5689 kelli.kerry-moran@iup.edu

Student Informed Consent Form (continued)

VOLUNTARY CONSENT FORM:

I have read and understand the information on the form and I consent to the terms of this study. I understand that the students' responses are completely confidential. I have the right to withdraw at any time. I have received an unsigned copy of this Informed Consent Form to keep in my possession.

Student Name (PLEASE PRINT)					
Signature					
Date					

I certify that I have explained to the above individuals the nature and purpose, the potential benefits, associated with participants in this research study, and have answered any questions that have been raised.

Date

Principal Investigator's Signature

Appendix C TEM Survey Gender: ___Male ___Female

Student Interest Survey: Technology

Instructions: The following statements relate to beliefs and interest in technology. Mark the column that most closely matches how you feel about each statement.

Beliefs about Technology	Strongly	Disagree	Neither	Agree	Strongly
	Disagree				Agree
I enjoy technology class					
I think I cold be a good					
technologist					
I like to find answers to					
questions by doing					
experiments					
I get to do experiments in my					
technology class					
Being a technologist would be					
exciting					
Technology is difficult for me					
I like to use the technology					
book to learn technology					
Technology is useful in					
everyday life					
Studying hard in technology is					
not cool					
Technologists help make our					
lives better					
Being a technologist would be					
a lonely job					
I want to take more technology					
classes					

Interest in Technology	Strongly	Disagree	Neither	Agree	Strongly
	Disagree				Agree
I think technology is					
important only at school					
I like to use computers to					
learn about technology					
Technology tests make me					
nervous					
I like to use technology					
equipment to study					
technology					
I don't usually try my best in					
technology class					
The things we study in					
technology are not useful to					
me in daily living					
I like to work in a small group					
in technology class					
Technology class activities					
are boring					
Finishing high school is very					
important to me					
I get better grades then most					
of my classmates in school					
I always give my best effort in					
my school homework					
I like being in school					
My family cares about the					
grades I get in school					
I like technology more then					
all other subjects in school					
My friends and I compete for					
the highest test scores in					
technology class					
I will definitely go to college					
someday					

Student Interest Survey: Engineering

Instructions: The following statements relate to beliefs and interests in engineering. Mark the column that most closely matches how you feel about each statement.

Beliefs about Engineering	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy engineering class	Disugree				ingi ee
I think I could be a good					
engineer					
I like to find answers to					
questions by doing					
experiments					
I get to do experiments in					
my engineering class					
Being a engineer would be					
exciting					
Engineering is difficult for					
me					
I like to use the engineering					
book to learn engineering					
Engineering is useful in					
everyday life					
Studying hard in engineering					
is not cool					
Engineers help make our					
lives better					
Being a engineer would be a					
lonely job					
I want to take more					
engineering classes					

Beliefs about Engineering	Strongly	Disagree	Neither	Agree	Strongly
I think ongin coring is	Disagree				Agree
i unink engineering is					
I like to use computers to					
learn about engineering					
Engineering tests make me					
nervous					
I like to use engineering					
equipment to study					
engineering					
I don't usually try my best in					
engineering class					
The things we study in					
engineering are not useful to					
me in daily living					
I like to work in a small					
group in engineering class					
Engineering class activities					
are boring					
Finishing high school is very					
important to me					
I get better grades than most					
of my classmates in school					
I always give my best effort					
on my school homework					
I like being in school					
My family cares about the					
grades I get in school					
I like engineering more then					
all other subjects in school					
My friends and I compete for					
the highest test scored in					
engineering class					
I will definitely go to college					
someday					

Student Interest Survey: Math

Instructions: The following statements relate to beliefs and interests in engineering. Mark the column that most closely matches how you feel about each statement.

Beliefs about Math	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I enjoy math class					8
I think I could be a good					
mathematician					
I like to find answers to					
questions by doing					
experiments					
I get to do experiments in					
my math class					
Being a mathematician					
would be exciting					
Math is difficult for me					
I like to use the math book					
to learn math					
Math is useful in everyday					
life					
Studying hard in math is not					
cool					
Mathematicians help make					
our lives better					
Being a mathematician					
would be lonely					
I want to take more math					
classes					

Beliefs about Math	Strongly	Disagree	Neither	Agree	Strongly
	Disagree				Agree
I think math is important					
I like to use computers to					
learn about math					
Math tests make me					
nervous					
I like to use math					
equipment to study math					
I don't usually try my best					
in math class					
The things we study in					
math are not useful to me					
in daily life					
I like to work in a small					
group in math class					
Math class activities are					
boring					
Finishing high school is					
very important to me					
I get better grades then					
most of my classmates in					
school					
I always give my best effort					
on my school work					
I like being in school					
My family cares about the					
grades I get in school					
I like math more then all					
other subjects in school					
My friends and I compete					
for the highest scores in					
math class					
I will definitely go to					
college someday					